MONTHLY BULLETIN

OF THE

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

(ENGLISH EDITION)

PUBLISHING and EDITORIAL OFFICES : 74, RUE DU PROGRÈS, BRUSSELS.

Yearly prepaid subscription { **Belgium . . . . . 70 Belgas** / **Other countries . . 75 Belgas** } including postage

Price of this single copy : 8 Belgas (not including postage).

(1 Belga = 5 Belgian francs.)

Subscriptions and orders for single copies (January 1931 and later editions) to be addressed to the General Secretary, International Railway Congress Association, 74, rue du Progrès, Brussels (Belgium).

Orders for copies previous to January 1931 should be addressed to Messrs. Weissenbruch & Co. Ltd., Printers, 49, rue du Poinçon, Brussels.

Advertisements : All communications should be addressed to the Association, **74, rue du Progrès, Brussels.**

CONTENTS OF THE NUMBER FOR NOVEMBER 1935.

LIBRARY

OF THE

Permanent Commission of the International Railway Congress Association.

READING ROOM : 74, rue du Progrès, Brussels.

Works in connection with railway matters which are presented to the Permanent Commission are mentioned in the « Bulletin ». They are filed and placed in the library. If the Executive Committee deems it advisable, they are made the subject of a special notice. Books and publications placed in the reading room may be consulted by any person in possession of an introduction delivered by a member of the Association. Books, etc., may not be taken away except by special permission of the Executive Committee.

The Permanent Commission of the Association is not responsible for the opinions expressed in the articles published in the Bulletin.

Editions in **French** and in **German** are also published.

Vol. XVII. — No. 11. November 1935.

BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

[621. 132. 3 (.42) & 625. 132 (.42)] 625. 232 (.42)]

The « Silver Jubilee » Train, London and North Eastern Railway,

by O. BULLEID,
Assistant to the Chief Mechanical Engineer, London and North Eastern Railway.

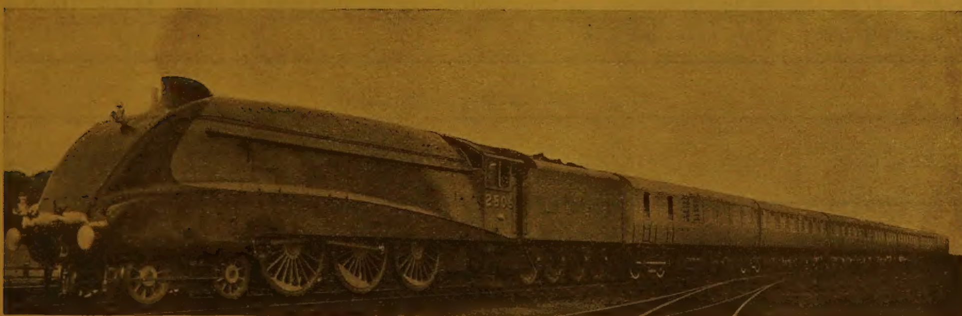


Fig. 1. — The « Silver Jubilee » train.

The London & North Eastern Railway introduced on the 30th September, 1935, a four-hour service between London (King's Cross) and Newcastle including an intermediate stop at Darlington, the distance being 268 miles. This train has been named « The Silver Jubilee », in celebration of H. M. King George's twenty five years' reign, and the complete engine and train is shewn in the photograph figure 1.

The diagram, figure 2, is a gradient section of the line and shews the arduous nature of much of the journey.

The train is a limited one, its composition being as shewn on the diagram, figure 3.

The train timing is as follows :

Point to point mileages, running times and speeds.

Newcastle, Darlington, King's Cross.

Distance from Newcastle.		STATION.			Point to point			
Miles.	Chns.			a. m.	Time. Mins.	Distance. Miles.	Chns.	Speed. M.h.p.
		Newcastle (Central) . .	dep.	10. 0				
5	39	Birtley	pass.	10. 8	8	5	39	41.2
14	3	Durham	»	10.18	10	8	44	51.3
23	18	Ferryhill	»	10.28	10	9	15	55.1
36	6	»	»	10.40	12	12	68	64.2
		Darlington	arr.	10.42				
41	21	Eyrholme	dep.	10.48	6	5	15	51.9
50	20	Northallerton	pass.	10.55	7	8	79	77.0
58	—	Thirsk	»	11. 1	6	7	60	77.5
69	2	Alne	»	11. 9	8	11	2	82.7
80	16	York	»	11.19	10	11	14	67.1
94	2	Selby	»	11.33	14	13	66	59.3
108	11	Shaftholme Jcn.	»	11.45	12	14	9	70.6
112	30	Doncaster (Central) . .	»	11.49	4	4	19	63.5
				p. m.				
129	57 3/4	Retford	»	12. 3	14	17	27 3/4	74.3
148	18 3/4	Newark	»	12.19	16	18	41	69.4
162	70 1/2	Grantham	»	12.32	13	14	51 3/4	67.6
191	78	Peterborough (North) . .	»	12.56	24	29	7 1/2	72.7
209	37 1/4	Huntingdon (North) . .	»	1 12	16	17	39 1/4	65.6
236	33 1/4	Hitchin	»	1.33	21	26	76	77.0
250	52 1/2	Hatfield	»	1.44	11	14	19 1/4	77.7
268	27	King's Cross	arr.	2. 0	16	17	54 1/2	66.3

Overall speed : 67.07 miles per hour.

King's Cross, Darlington, Newcastle.

Distance from Kings' Cross.		STATION.			Point to point			
Miles.	Chns.			p. m.	Time. Mins.	Distance. Miles.	Chns.	Speed. M.h.p.
		King's Cross	dep.	5.30				
17	54 1/2	Hatfield	pass.	5.48	18	17	54 1/2	58.9
31	73 3/4	Hitchin	»	5.59	11	14	19 1/4	77.7
58	69 3/4	Huntingdon (North) . .	»	6.19	20	26	76	80.8
76	29	Peterborough (North) . .	»	6.35	16	17	39 1/4	65.6
105	36 1/2	Grantham	»	6.59 1/2	24 1/2	29	7 1/2	71.3
120	8 1/4	Newark	»	7.11 1/2	12	14	51 3/4	73.2
138	49 1/4	Retford	»	7.27	15 1/2	18	41	71.7
155	77	Doncaster (Central) . .	»	7 41	14	17	27 3/4	74.3
160	16	Shaftholme Jcn.	»	7.45	4	4	19	63.5
174	25	Selby	»	7.56 1/2	11 1/2	14	9	73.6
188	11	York	»	8. 9	12 1/2	13	66	66.4
199	25	Alne	»	8.20	11	11	14	60.9
210	27	Thirsk	»	8.29	9	11	2	73.5
218	7	Northallerton	»	8.35	6	7	60	77.5
227	6	Eyrholme	»	8.42	7	8	79	77.0
232	21	Darlington	arr.	8.48	6	5	15	51.9
		»	dep.	8.50				
245	9	Ferryhill	pass.	9. 3	13	12	68	59.3
254	24	Durham	»	9.15	12	9	15	45.9
262	68	Birtley	»	9.23	8	8	44	64.1
268	27	Newcastle (Central) . .	arr.	9.30	7	5	39	47.0

Overall speed : 67.07 miles per hour.

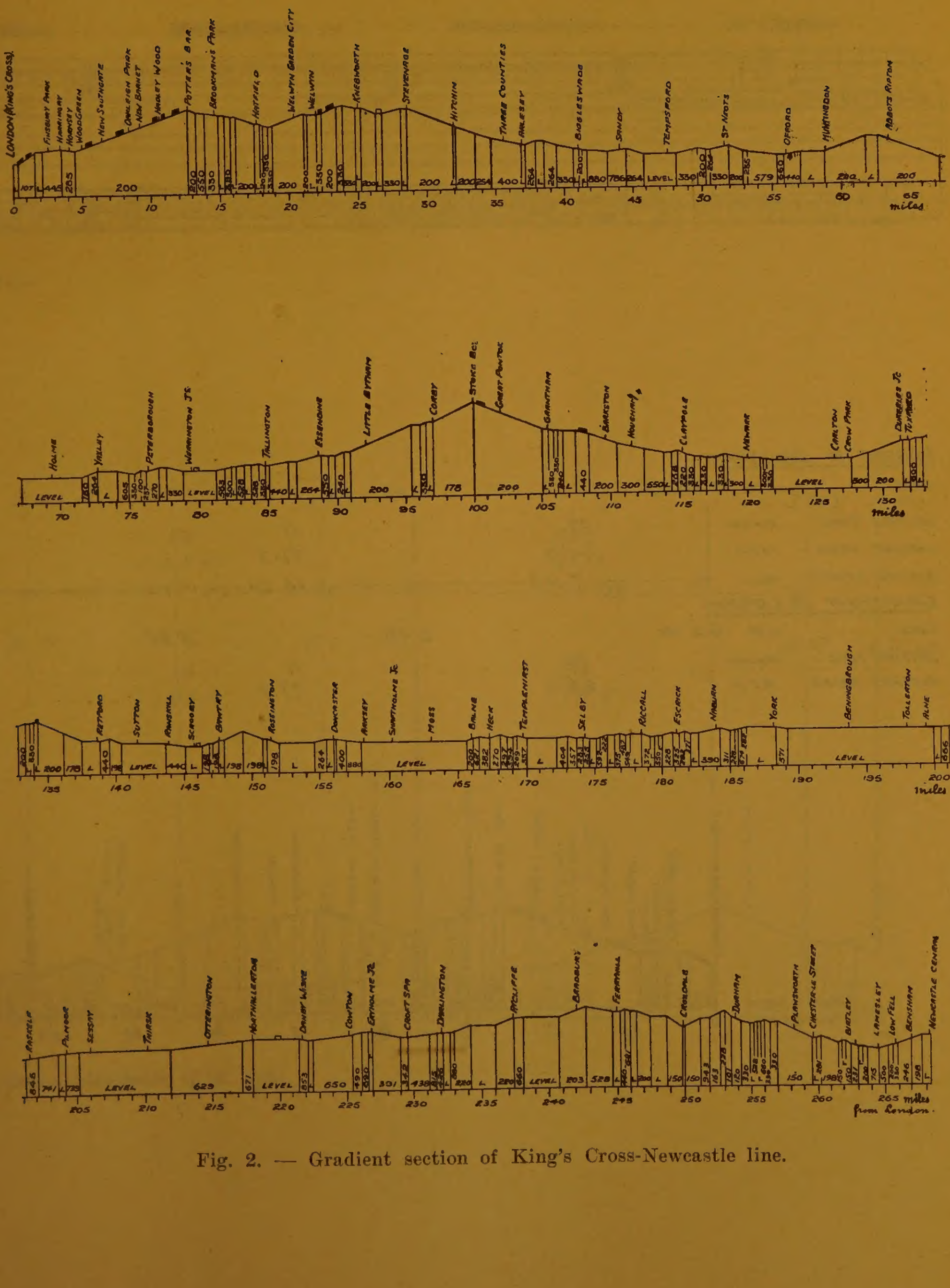


Fig. 2. — Gradient section of King's Cross-Newcastle line.

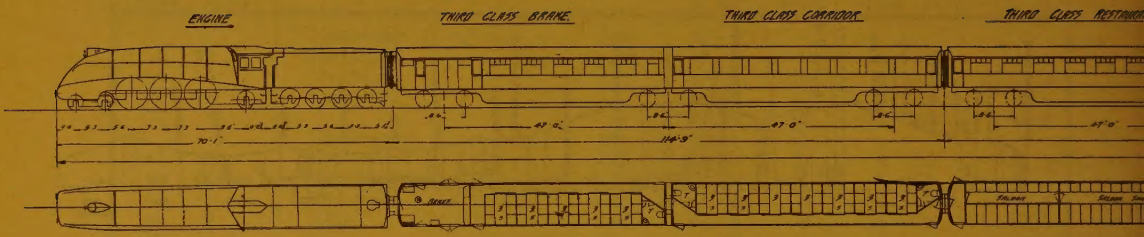


Fig. 3. —

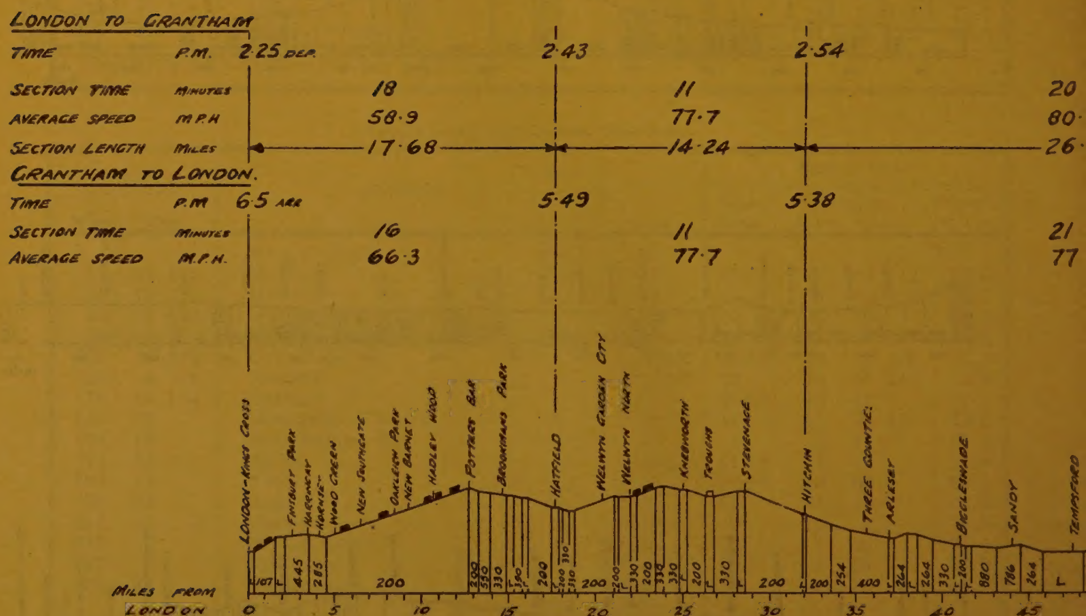
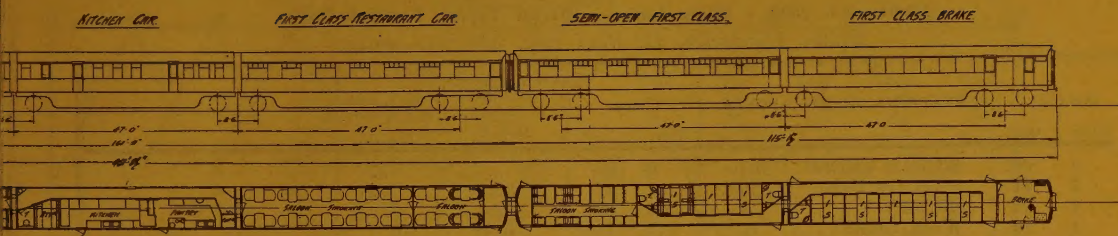
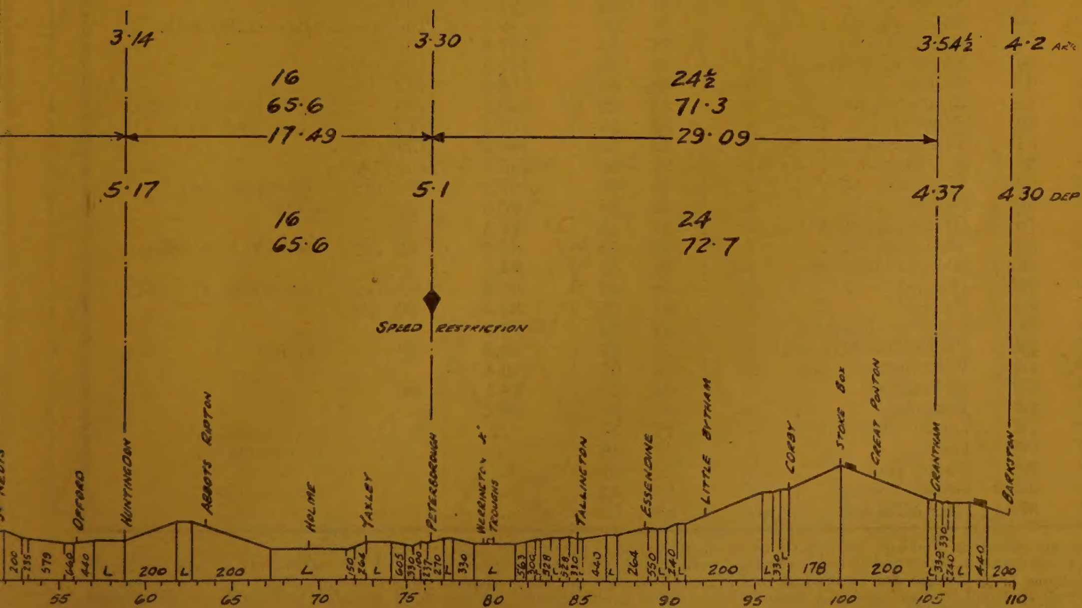


Fig. 4. — Gradients, speeds and tim



tion of train.



r special train, September 27th. 1935.

The diagram, figure 4, shews the timings, speeds and gradients as between London and Grantham as scheduled for the test run on September 27th, the sectional timings being similar to those given above; the actual log of the trial is as follows :

Engine No. 2509, « Silver Link ». Driver Taylor, Fireman Luty.

Load : 7 vehicles. 220 tons tare, 230 tons gross.

Distance. Miles.	Chs.	STATIONS OR MILE-POSTS.		Times. Min.	Sec.	Average speeds, station to station. M.p.h.	Max. and min. speeds. M.p.h.	
0	00	KING'S CROSS .	dep.	0	00	...	...	
2	41	Finsbury Park .	pass.	4	42	32.1	...	
4	04	Hornsey . . .	»	6	22	55.4	...	
4	78	Wood Green . .	»	7	11	68.0	70	
6	35	New Southgate .	»	8	26	70.2	71 1/2	Acceleration up con-
9	12	New Barnet . .	»	10	43	71.3	72	tinuous 1 in 200
10	46	Hadley Wood . .	»	11	53	73.3	74	grade.
12	57	Potter's Bar . .	»	13	36	74.7	75	
14	51	Brookman's Park	»	15	00	82.5	...	
17	55	HATFIELD . .	»	17	07	86.5	...	
20	25	Welwyn Garden City	»	18	46	95.5	98	(mile-post 19).
22	00	Welwyn North .	»	19	52	92.1	90	
23	39	Woolmer Green .	»	20	52	89.3	88	
25	03	Knebworth . .	»	21	55	88.5	93 1/2	(mile-post 26 1/4).
28	46	Stevenage . . .	»	24	13	92.3	90	
30	00	Mile-post 30 . .	»	25	06	96.8	100	(first attained).
31	74	HITCHIN . .	»	26	14	101.9	107	
35	56	Three Counties .	»	28	20	107.9	109 1/2	
37	03	Arlesey . . .	»	29	03	112.0	112	
41	12	Biggleswade . .	»	31	22	106.8	105	(mile-post 38 1/2).
44	10	Sandy	»	32	59	110.4	112	(mile-post 43).
47	41	Tempsford . .	»	34	50	109.9	109 1/2	
51	58	St. Neot's . . .	»	37	13	106.0	104 1/2	
55	00	Mile-post 55 . .	»	39	03	107.2	109 1/2	(mile-post 54).
55	76	Offord	»	39	41	90.0	85	*slack.*
58	70	HUNTINGDON .	»	41	41	87.5	88	
62	00	Mile-post 62 . .	»	43	53	85.2	83 1/2	(top of 1 in 200).
63	42	Abbot's Ripton .	»	44	58	84.5	...	
69	29	Holme	»	48	50	90.6	93 1/2	(mile-post 67 1/2).
72	48	Yaxley	»	51	08	84.5	80 1/2	
74	78	Fletton Junction	»	52	55	79.9	...	
76	29	PETERBOROUGH	»	55	02	39.3	20	*slack.*
79	40	Werrington Jun.	»	59	07	46.1	...	
84	67	Tallington . .	»	63	13	78.1	85	
88	52	Essendine . . .	»	65	58	83.2	...	
92	18	Little Bytham .	»	70	35	...	...	*signal check.*
97	08	Corby	»	77	49	...	...	*signal check.*
100	09	Stoke Box	»	80	51	...	...	
102	03	Great Ponton .	»	82	23	...	...	*signal check.*
105	37	GRANTHAM .	arr.	88	15	...	...	

Maximum speed on journey, 112 m.p.h. twice, near Arlesey and between Biggleswade and Sandy.

(*) Between mile-posts 30 and 55 (where brakes were applied for Offord curves) the speed was entirely at or over 100 m.p.h. This distance of 25.0 miles was covered in 13 minutes 57 seconds, at an *average* of 107.5 miles per hour.

(*) From Hatfield to Huntingdon a distance of 41 miles 15 chains was covered in 24 minutes 34 seconds, at an *average* of 100.6 miles per hour throughout.

(*) The entire distance covered at an *average* speed of 100 miles per hour continuously was approximately 43 miles.

(**) From Wood Green to Fletton Junction the distance of precisely 70 miles was covered in 45 minutes 44 seconds, at an average of 91.8 miles per hour. Fletton Junction marks the beginning of the severe slack through Peterborough station.

On the continuous 8 miles at 1 in 200 rising from mile-post 4 1/2 (Wood Green) to Potter's Bar, the speed steadily accelerated from 70 to 75 miles per hour.

The signal checks from Little Bytham onwards were due to the special train having overtaken the York and Harrogate express which had left King's Cross at 1.40 p.m., 45 minutes earlier. Apart from these delays, Grantham would have been reached without difficulty in 80 minutes from London.

(*) World's railway record, so far as can be authenticated, for either diesel or steam propulsion.

(**) World's record for steam traction.

Ivatt's speed diagram.

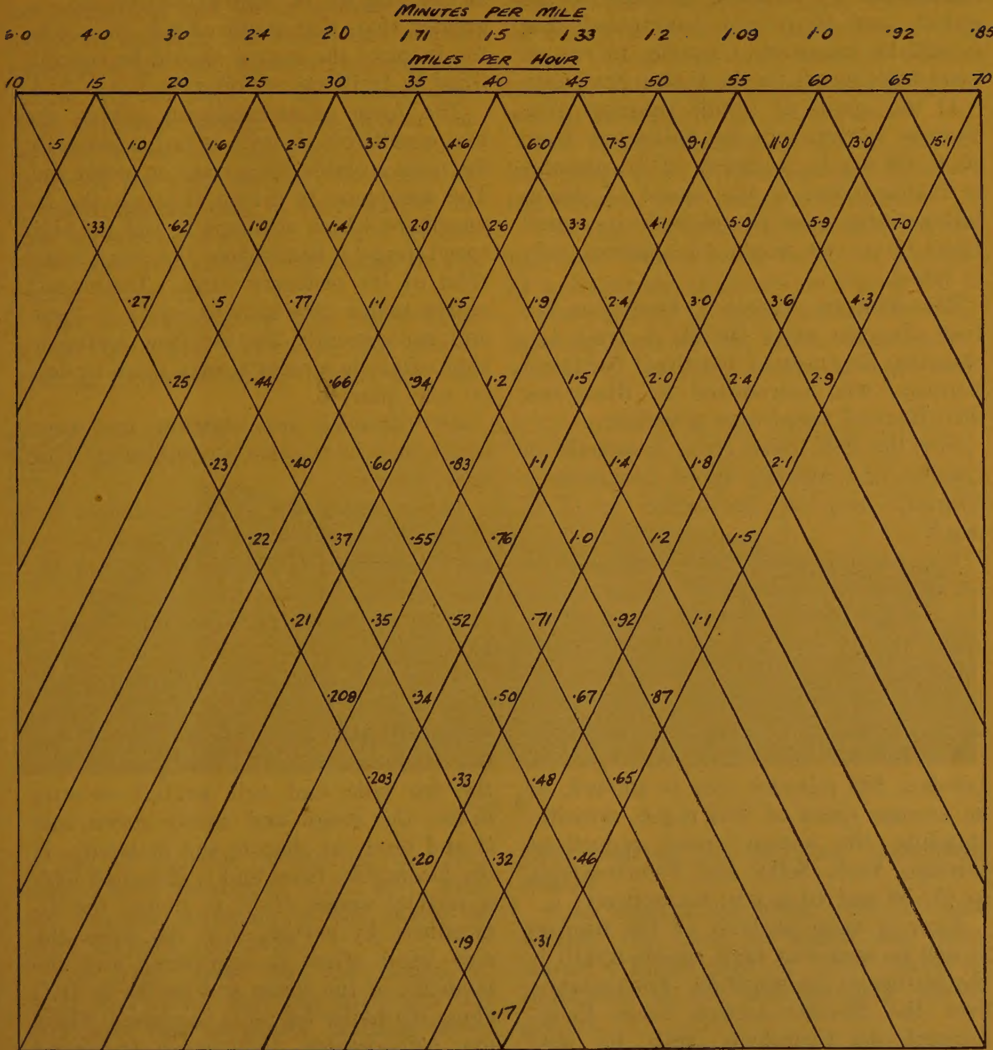


Fig. 5. — Diagram giving distance in miles necessary to be run at varying increased rates of speed to regain one minute lost at any given speed.

The figure at the apex of the triangle formed by the line from the speed at which one minute is lost and the speed run to regain time gives the miles required to be run at the latter speed.

Example : One minute lost at 35 m.p.h. can be regained by :
Running 2.6 miles at 45 m.p.h., or
» 1.5 » » 55 m.p.h.

Such high average speeds can only be maintained by running at high speeds uphill, and it is not anticipated that it will be necessary normally to run at extra high speeds on the falling gradients.

If the speed of uphill running of a 20-mile section can be increased from 40 to 60 m.p.h., a saving of 10 minutes is realised, but if the speed of downhill running over 20 miles is increased from 60 to 80 m.p.h., 5 minutes only is saved.

The diagram, figure 5, known as the Ivatt diagram, after Mr. H. A. Ivatt, Locomotive Engineer of the Great Northern Railway, who introduced it, illustrates the effect of speed over a section.

For the 268 miles from Newcastle to London, the average speed including a 2-minute stop at Darlington is 67.07 m.p.h.

For the 36 miles from Newcastle to Darlington 40 minutes is allowed and the average speed is only 54 m.p.h. This lower average speed is owing to restrictions of 25 m.p.h. through Durham and two other permanent speed restrictions of 20 m.p.h. owing to colliery workings.

For the 232 miles from Darlington to London, 198 minutes only is allowed, or an average speed of 70.3 m.p.h. notwithstanding the severe speed reductions through York, Selby and Peterborough, to 15, 30 and 10 m.p.h. respectively.

From a close analysis of the timings it will be seen that high speeds uphill is the feature of the schedule. For instance, over the 29-mile section from Peterborough to Grantham, with its long rising gradient of 9 miles varying from 1 in 200 to 1 in 178, 24 1/2 minutes is allowed in running, but in the opposite direction the time allowed is only reduced to 24 minutes, the speeds being 71.3 and 72.7 m.p.h. respectively.

As the power required to overcome the air resistance on the front of the engine at 70 m.p.h. is approximately 50 % greater than that required for 60 m.p.h., the front of the engine should be streamlined to facilitate running, and save fuel.

The form of streamlining giving the best results on aircraft is not necessarily the most suitable for a train or motor car. The aeroplane is driven through the atmosphere which envelops it and its high speed largely neutralizes the directional effet of the ordinary wind. Trains and racing motor cars have to follow a track, and consequently the air flow owing to side winds is almost always more or less on one quarter.

An extended investigation has been made into locomotive streamlining from four aspects :

(1) reducing the head resistance;

(2) lifting the steam and smoke;

(3) minimising the disturbance of the atmosphere alongside the train, and

(4) not interfering with the driver's view.

A wind other than a head-on wind causes an increase in pressure on the windward side of the boiler barrel, but also induces a reduced air pressure on the lee side and this partial vacuum draws the steam and smoke down into it and tends to obscure the look-out. If the locomotive front end is designed with a vertical wedge front to pierce the atmosphere by parting it to the sides, the side wind effect is aggravated and the tendency of the steam and smoke to drift along the boiler barrel is increased. Then, too, considerable disturbance is caused laterally and this is felt by passing trains.

For these reasons, Mr. Gresley, C. B. E., Chief Mechanical Engineer, L. N. E. R., decided that the best form of front end was a horizontal wedge, as this would cause an upwardly rising current of air

to sweep past the chimney above the boiler barrel top, and by its velocity would assist in carrying the steam and smoke clear over the cab, besides avoiding any lateral displacement of the atmosphere. The running boards were given an aerofoil form to minimise the disturbance of the atmosphere. The form of streamlining adopted is very similar to that incorporated by M. Bugatti in his high-speed railcars in France and in his racing motor cars.

The streamlining of the engine and tender is clearly shewn in the photographs, figures 6 and 7, which are side views of the engine and figure 8, a front view. The photograph figure 9 shows the casing in course of erection.

The absence of side screens which obstruct the enginemen's forward view will be noticed.

The tender has been built up to the load gauge so as to minimise the disturbing effect of any change of section.

The space between the cab and tender has been covered in by means of a sheet of indiarubber as shewn on figure 6.

The chimney is semi-circular forward, tapering back behind again with the intention of avoiding eddy currents and

Fig. 6.

as far as possible preventing the formation of a vacuum in front of it with the resulting tendency of the smoke to work forward and down.

The trials shew that the design is most successful, and has overcome the difficulty due to smoke drifting down the front of the cab. Covering in the space between the engine cab and the tender has also prevented the smoke being drawn down into the cab. Instead, the smoke stream continues to the back of the tender and has stopped the inconvenience caused by coal dust from the tender being drawn on to the footplate, making the footplate noticeably cleaner.

Four engines are being built for this service, the first of which has been named « Silver Link ». This engine is illustrated in the accompanying photographs.

The streamlined casing of the front end covers over the smokebox front end and door. In order to give access to the smokebox, the sloped front plate is divided into two parts, the larger hinged at the top lifting upwards and the lower hinged at the bottom lifting forward and downwards over the buffers. These doors

Fig. 9.

Fig. 7.

are operated from the ground by a handle on a cross shaft in front of the smokebox, the lower door overlapping the top door when closed.

Figure 10 shews these front covers open.

Inspection doors have been provided along the sides of the engine to give access to the different parts of the motion.

Figure 11 shews the engine and tender in outline.

The engine is a three-cylinder simple expansion *Pacific* type locomotive with an eight-wheeled tender.

The boiler pressure has been increased to 250 lb. per sq. inch. The grate area is 41 1/4 sq. feet, a new design of firebar being used giving air space openings equal to 56 % of the grate area. Part of the grate is arranged to drop. The ashpan is completely welded and the design gives a free air flow under the outer side bars.

The boiler barrel is made in two courses. The first course is parallel, 5 ft. 9 3/4 in. outside diameter, the plates being 13/16 inch thick; the second course is conical, having a maximum diameter of 6 ft. 5 in. and is of plate 7/8 inch thick. The distance between tube plates is 17 ft. 11 3/4 in.

The steam collector is a steel pressing integral with the dome, the steam supply being taken through a series of 1/2-inch slots cut in the top of the barrel plate. The firebox is of copper and, including the combustion chamber, is 10 ft. 1 3/4 in. long. Figure 12 is a view of the copper firebox. The throat plates of both the copper box and of the outer casing are each in one piece. The copper wrapper plates are 9/16 inch thick and the tube plate 1 1/4 inches thick.

The regulator is of the double beat

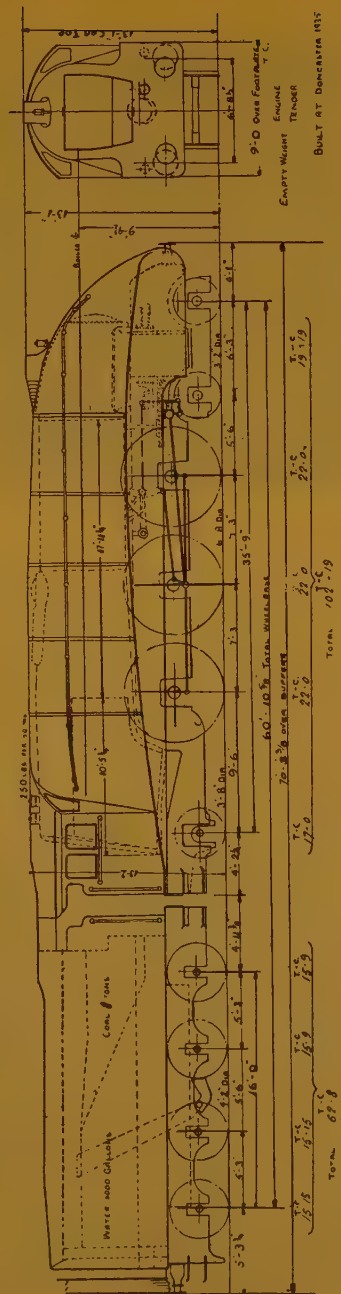


Fig. 11.

Fig. 12.

type, and feeds into a main steam pipe of 7-inch diameter.

The superheater is of the Robinson type, the 43 elements being expanded into a cast steel header. The elements are of the short loop type and extend to within 9 inches of the copper tubeplate.

The whole of the boiler barrel and firebox are insulated with mattresses consisting of five layers of « Alfol » foil held in 1 1/2 inch mesh galvanised wire netting. The outer covering is steel sheeting 16 S. W. G. thick.

The boiler is fed by two injectors, that on the right hand side of the engine being a Davies & Metcalfe No. 10 exhaust steam injector, and that on the left hand side a Gresham & Craven No. 11 live steam under-footplate injector.

The three cylinders are each 18 1/2 inches in diameter by 26 inches stroke. In designing these cylinders, particular attention was paid to the size and shape of the steam and exhaust passages, so that they should offer the minimum restriction to the flow of the steam. In addition the passages were carefully gone over and all roughness removed. Each cylinder is cast as a separate unit, the exhaust from the outside cylinders being carried to the blast pipe base through a cast steel saddle. The piston valves are of the narrow ring type with ring control. The valves are 9 inches in diameter with a steam lap of 1 5/8 inches. Each cylinder has its own 5-inch diameter steam pipe from the header, and special care has been exercised to make the exhaust passages smooth in order to reduce the friction. The drawing, figure 13, shews the piston valves in question.

The blast pipe nozzle is of 5 1/4-inch diameter and is provided with a jumper ring of the type introduced by the late Mr. Churchward on the Great Western Railway, to relieve back pressure when working the engine at a long cut-off.

The piston and rod are combined in one forging of British Standard Specification class « C » steel. The connecting and coupling rods of nickel-chrome steel are similar to those at present fitted to the ordinary *Pacific* engines.

40 % of the total reciprocating weight is balanced at the wheel rim, the engine being balanced in accordance with Professor Dalby's method.

The accuracy of the balancing was verified by testing the wheels on the balancing machine.

The valve gear is of the Company's standard type in which the outside valves are operated by means of Walschaerts gear, and the inside valve by the Gresley gear incorporating a system of equal and 2 : 1 levers. The valve gear throughout is fitted with ball and roller bearings. The maximum cut-off is 65 %, at which position the valve travel is 5 3/4 inches.

The coupled axleboxes are lubricated

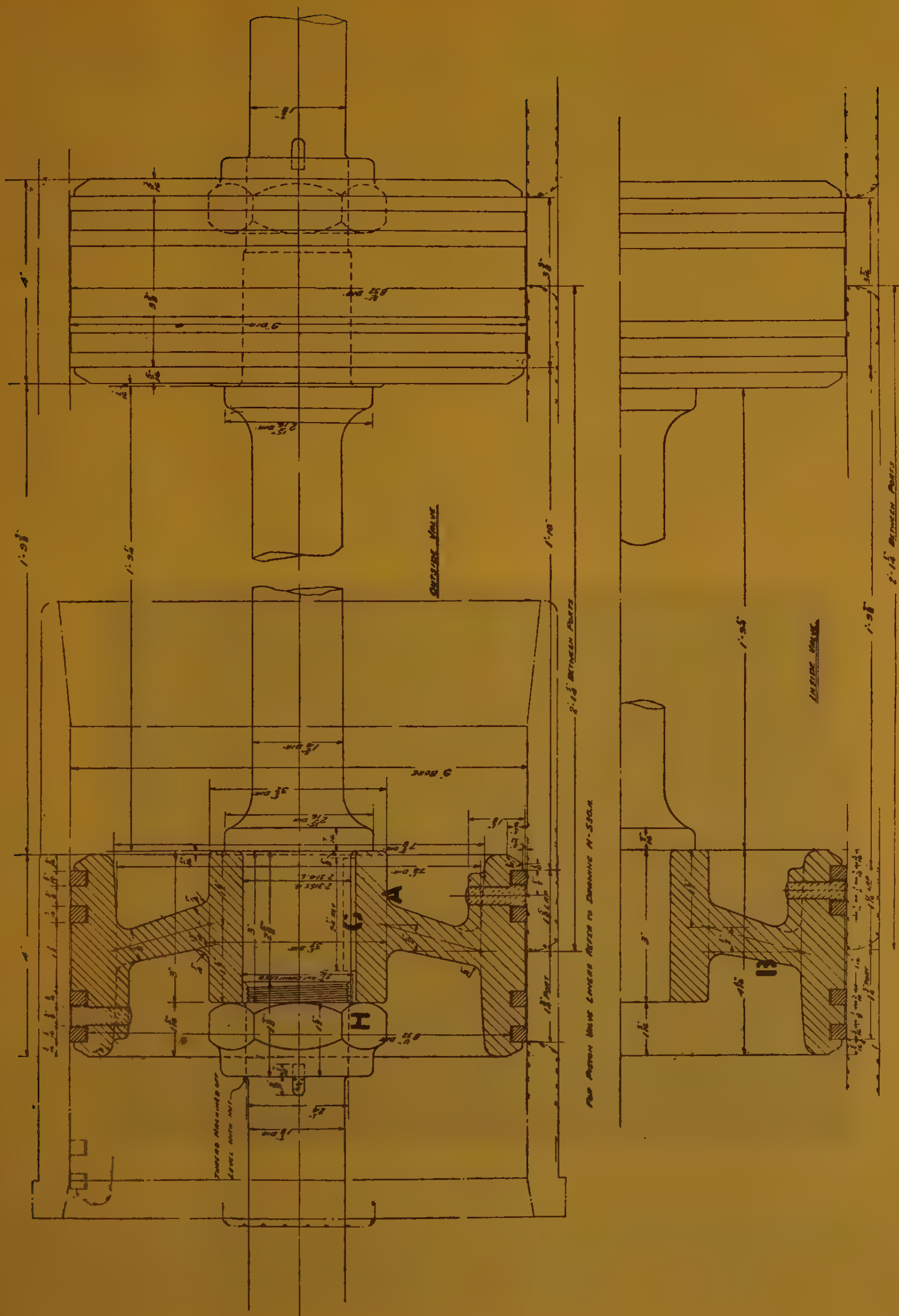


Fig. 13. — The piston valves.

by means of a Wakefield six-feed mechanical lubricator and Armstrong oiler pads are used in the axlebox trays.

A Wakefield six-feed mechanical lubricator is also used for the lubrication of the valves and cylinders, one feed being placed in each steam pipe and one on the top of each cylinder barrel.

The two lubricators are driven from one return crank on the right hand trailing crankpin, and the gear is fitted with ball bearings throughout. Four oil boxes each with nine syphon feeds lubricate the valve spindles, piston rods etc.

The locomotive is fitted with the automatic vacuum brake, there being one 24-inch and two 21-inch diameter brake cylinders which transmit their pull to the main shaft.

The 30/20 mm. ejectors fitted on these engines are made by either Messrs. Gresham & Craven, or Messrs. Davies & Metcalfe.

The brake shafts are of forged steel, the brake arms and levers being electrically welded.

The front of the cab is V-shaped and provides an exceptionally wide angle of vision for the engine crew.

Reversing gear of the vertical screw type fitted with ball thrust washers and with a special vacuum locking apparatus is provided.

Bowden wire is used for the sand gear and cylinder cock controls, as well as for operating the whistle, the latter being of a special type fitted immediately in front of the chimney.

Fig. 14.

Bucket seats are provided for the driver and fireman and are shewn in figure 14.

In addition to the usual cab fittings, a Cambridge pyrometer and Flaman type E7 speed recorder are also fitted.

The tender is of the corridor eight-wheeled type and is equipped with well and water scoop, its capacity being 5 000 gallons of water and 8 tons of coal.

The tender is fitted with standard Pullman vestibule and buckeye couplers as used on the Company's passenger vehicles, and the back is rounded to conform to the shape of the carriages to which it is coupled.

All carrying wheels, both engine and tender, were carefully balanced by running them on the wheel balancing machine up to a speed of 100 m.p.h.

The principal dimensions and ratios are given below :

Cylinders.	Three—	18 1/2″ diam. × 26″ stroke.
Wheels.	Bogie—	3′ 2″ diam.
	Coupled—	6′ 8″ »
	Trailing—	3′ 8″ »
Wheelbase.	Coupled wheels	14′ 6″
	Total engine wheelbase	35′ 9″
	Total engine and tender	60′ 10 5/8″
Journals.	Bogie	6 1/2″ diam. × 9″ long.
	Coupled wheels	9 1/2″ diam. × 11″ »
	Trailing	6″ diam. × 11″ »
Boiler—Outside length of firebox overall		10′ 5 5/8″
» » » » at bottom		6′ 8″
	Maximum diameter of barrel	6′ 5″
	Thickness of barrel plates	13/16″ × 7/8″
	Thickness of wrapper plates	9/16″
Tubes—Small, Material		Steel with copper ends.
	Number	121.
	Outside diameter	2 1/4″
	Thickness	10 I.W.G.
	Length between tubeplates	17′ 11 3/4″
	Superheater flues, Material	Steel.
	Number	43.
	Outside diameter	5 1/4″
	Thickness	5/32″
Heating surface :		
	Firebox	231.2 sq. ft.
	Tubes	1 281.4 » »
	Flues	1 063.7 » »
Total evaporative heating surface		2 576.3 » »
Superheater elements		749.9 » »
Combined heating surface		3 325.2 » »
Grate area		41.25 sq. ft.
Tractive effort at 85 % boiler pressure		35 455 lb.
Adhesive weight		148 176 »
Adhesive factor		4.18
Weight of engine and tender (working order).		165 tons 7 cwts.

The train, which is known as « The Silver Jubilee » is 392 feet long and consists of seven vehicles, the train formation being as under :

Third-class brake	Articulated	= 30 seats.
Third-class corridor		= 42 seats.
Third-class restaurant car	Articulated	= 48 seats.
Kitchen car		
First class restaurant car		= 28 seats.
First-class semi-open	Articulated	= 30 seats.
First-class brake		= 20 seats.

Fig. 15.

The train is vestibuled throughout and has a total seating capacity of 198, the tare weight being 220 tons.

The bodies of the twin articulated vehicles and the two restaurant cars of the triplet set are each 56 ft. 2 1/2 in. long and 9 feet wide, whilst the kitchen car of the triplet set is 45 ft. 11 in. long and 9 feet wide.

Figure 15 shows the articulated ends and the way the bodies are carried by the bogies, and figure 16 the Pullman vestibules between two units. Figure 17 shows an outer bogie.

The articulation of railway coaches was first invented by Mr. Gresley in 1907, since which date 480 articulated sets have been put into service on the L. N. E. R. Company's lines alone.

The exterior finish of the train is a distinct departure from the Company's usual practice. Instead of the standard varnished teak exterior, the bodies are panelled in No. 16 gauge steel on the outside, the steel panels being levelled off with a special stopping which is rubbed down to give a smooth level surface.

Fig. 16.

Fig. 17.

The panels are then covered with aluminium Rexine which is secured by a special adhesive known as LK 3134, manufactured by Imperial Chemical Industries Ltd. The cornices, door and window facias and the beading between the windows and also the bottom beading are made of Firth's Staybrite steel; the advantage of dividing up the exterior by these Staybrite strips is that in the event of the Rexine being damaged, it is a simple matter to remove the strips surrounding the damaged piece, replace the damaged material and restore the Staybrite strips to their normal position, without taking the unit out of service.

The roof following the Company's standard practice is of tongued and grooved boards coated with white lead and covered with roofing canvas, which is then painted with lead paint. In place of the usual finishing coats of white lead paint, these roofs have been finished in a special aluminium paint manufactured by Messrs. Docker Brothers, incorporating a specially fine aluminium powder. The train name is painted on zinc plates fastened directly onto the roof above the cant rail, in aluminium letters on a blue ground.

The roof is free from projections of any kind, torpedo extractors having been made unnecessary by the air conditioning equipment installed.

The droplight incorporating a cast Alpax frame presented some difficulty owing to the flush exterior finish required. The problem was solved as shown on the drawing, figure 18.

Exterior projections on the sides have been reduced to a minimum, and, in order to reduce the air resistance, a skirting has been fitted between the bogies extending from the bottom of the body to within 10 1/4 inches of the rail. These skirtings have been lined with cloth on the inside, to prevent drumming. The spaces between the articulated ends of the vehicles have been closed by means of a special rubber sheeting with aluminium finish supplied by Messrs. George Spencer Moulton & Co., which is fitted with a slight initial tension. The shape adopted at the bottom is the result of experiment and prevents the rubber tearing. This rubber sheeting is also shown on figure 15.

The bogies are of the L. N. E. R. standard four-wheeled compound bolster

type, and are shown on the drawing, figure 19.

The bolster springs used are of the special Timmis section manufactured by Messrs. Turton Brothers & Matthews. Each centre bolster is fitted with two nests of two springs, those on the outer bogies having a deflection per nest of 19/64 inch per ton, whilst those under the articulated ends have a deflection of 1/4 inch per ton. The four nests of springs on the outer bolsters of all bogies have a deflection of 41/64 inch per ton.

The side bearing springs, made by Messrs. Wilford & Co., are 4 feet long, the section of the plate being 4 inches by 1/2 inch, springs of 9, 10 and 11 plates being used according to the load carried, the deflections per ton being 0.85, 0.76 and 0.7 inch respectively. The four springs on each bogie are carefully matched to give the same deflection per ton.

The underframes are of steel rigidly trussed, the whole being fabricated by means of electric welding. The electrodes used were « Murex » Ironex, Nos. 6, 8 and 10 S. W. G.

The body framing is of Burmah teak throughout, the floors being bolted directly on the underframes.

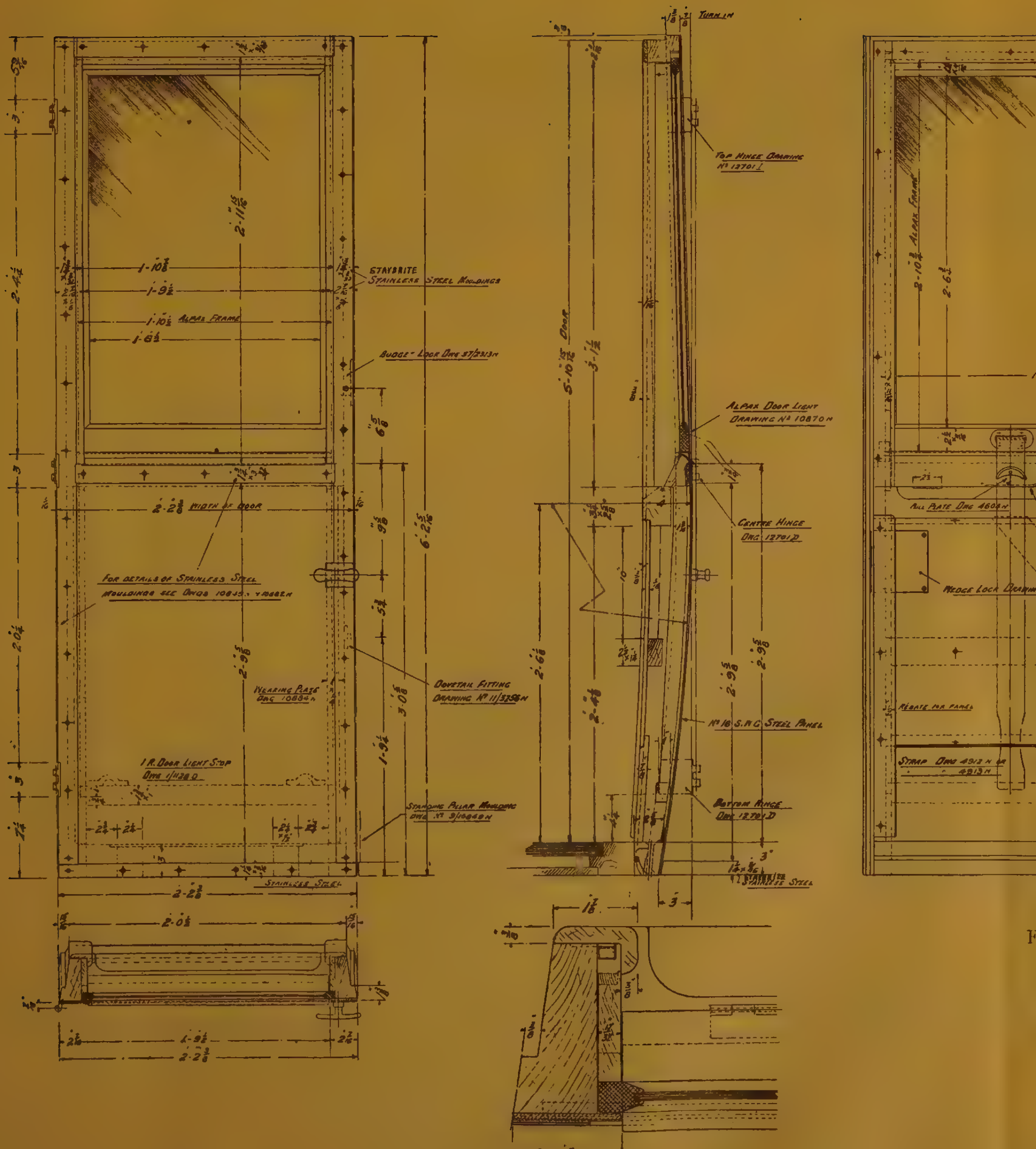
The steel panels are bedded to the pillars with a special paste before being finally screwed into position. All edges of the Rexine fabric are covered by the Staybrite steel strips previously referred to.

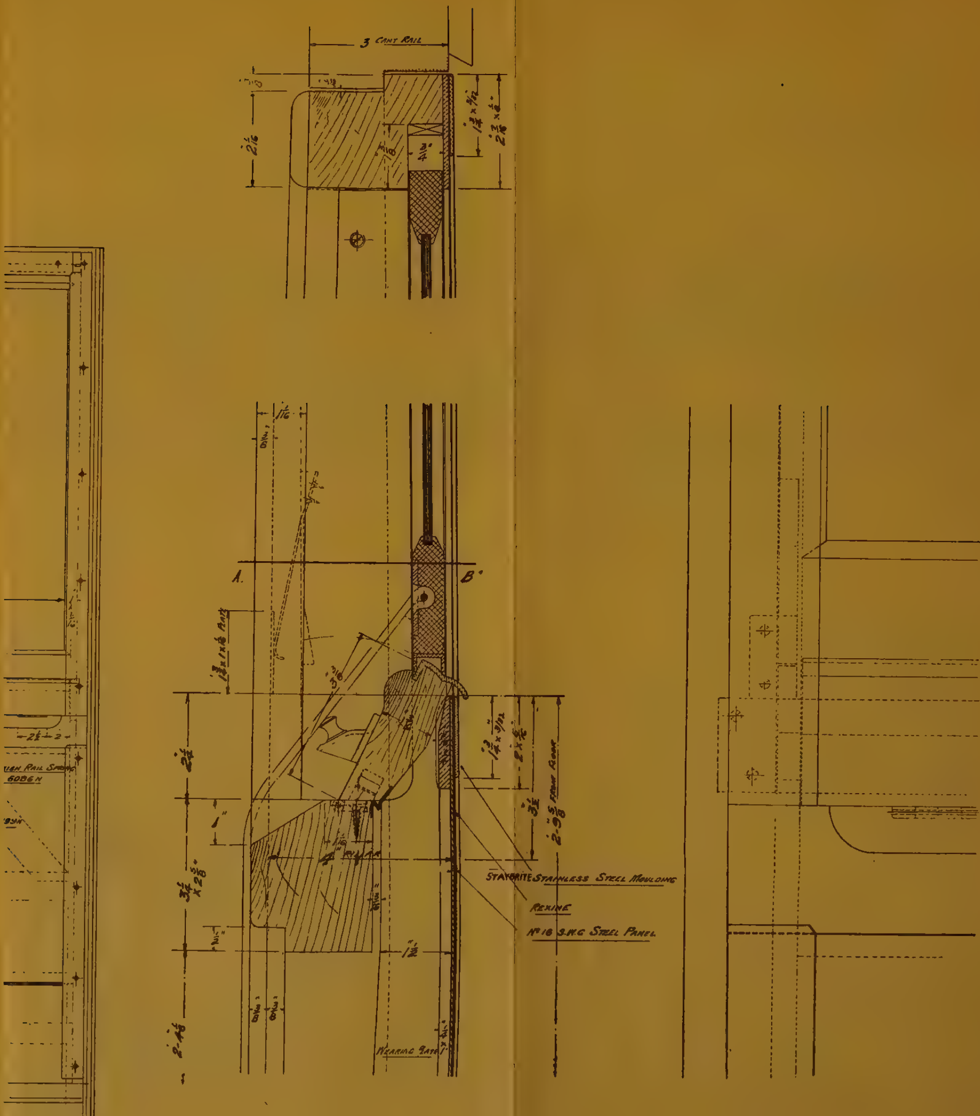
To deaden the noise to be expected when running at high speeds, the floors, roofs and walls have been insulated with Roberts « Asbestos Acoustic » blanket, whilst further precautions have been taken by electrically welding Messrs. Beckett, Laycock & Watkinson's special dovetailed steel sheeting between the underframe members, and filling the space thus formed between the sheeting and the floor with Roberts asbestos spray insulation. The large side windows of the saloons and compartments are fitted with double 1/4 inch thick polished plate glass having an air space of 1/4 inch between, in order to reduce to a minimum the transmission of heat and sound.

Ventilators are fitted above each restaurant car and compartment window. The ventilators are fitted with hinged flaps which cause the ventilator, when open, to extract air from the interior of the vehicle.

Plywood has been used throughout for the interior lining of each body with the exception of the ceilings which are of special millboard. All cross partitions with the exception of those in the restaurant cars are of block board.

The whole of the train with the exception of the kitchen car is fitted with Messrs. J. Stone & Company's automatic air conditioning and heating system. Fresh filtered air is forced into the compartments through outlets near the floor level, and in cold weather the air is heated to the required temperature according to the predetermined setting of a special compensated thermostat. The equipment consists of a unit, suspended from the underframe, which contains the necessary fan, air filters, and heating apparatus, from which the conditioned air is conveyed to the compartments by suitably lagged metal ducts, and passes to the outside atmosphere by means of extractor type sliding shutter ventilators situated over each body side light, and also through perforated metal grids situated over each compartment sliding door. It is found in service that not only is the temperature of the compartments maintained at the desired level but that there are no draughts. Moreover there is no condensation on the windows and,


STAYBRITE STAINLESS STEEL MOULDINGS
ALPAX FRAME
WIDTH OF DOOR
FOR DETAILS OF STAINLESS STEEL MOULDINGS SEE DWGS
DOVETAIL FITTING
STAINLESS STEEL
TURN IN
TOP HINGE DRAWING
ALPAX DOOR LIGHT
CENTRE HINGE
BOTTOM HINGE
STEEL PANEL
DOOR



18. — Arrangement of body side door.

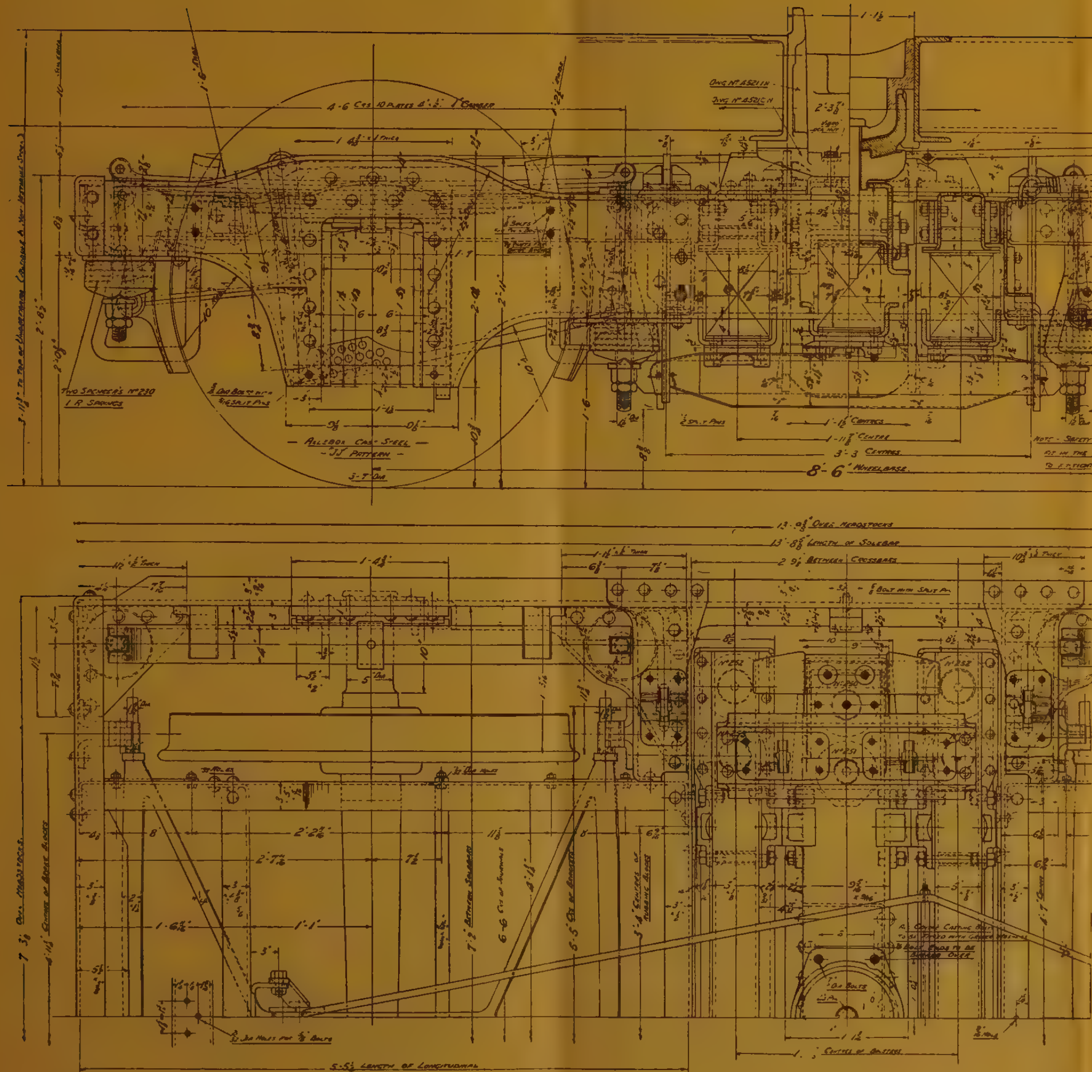
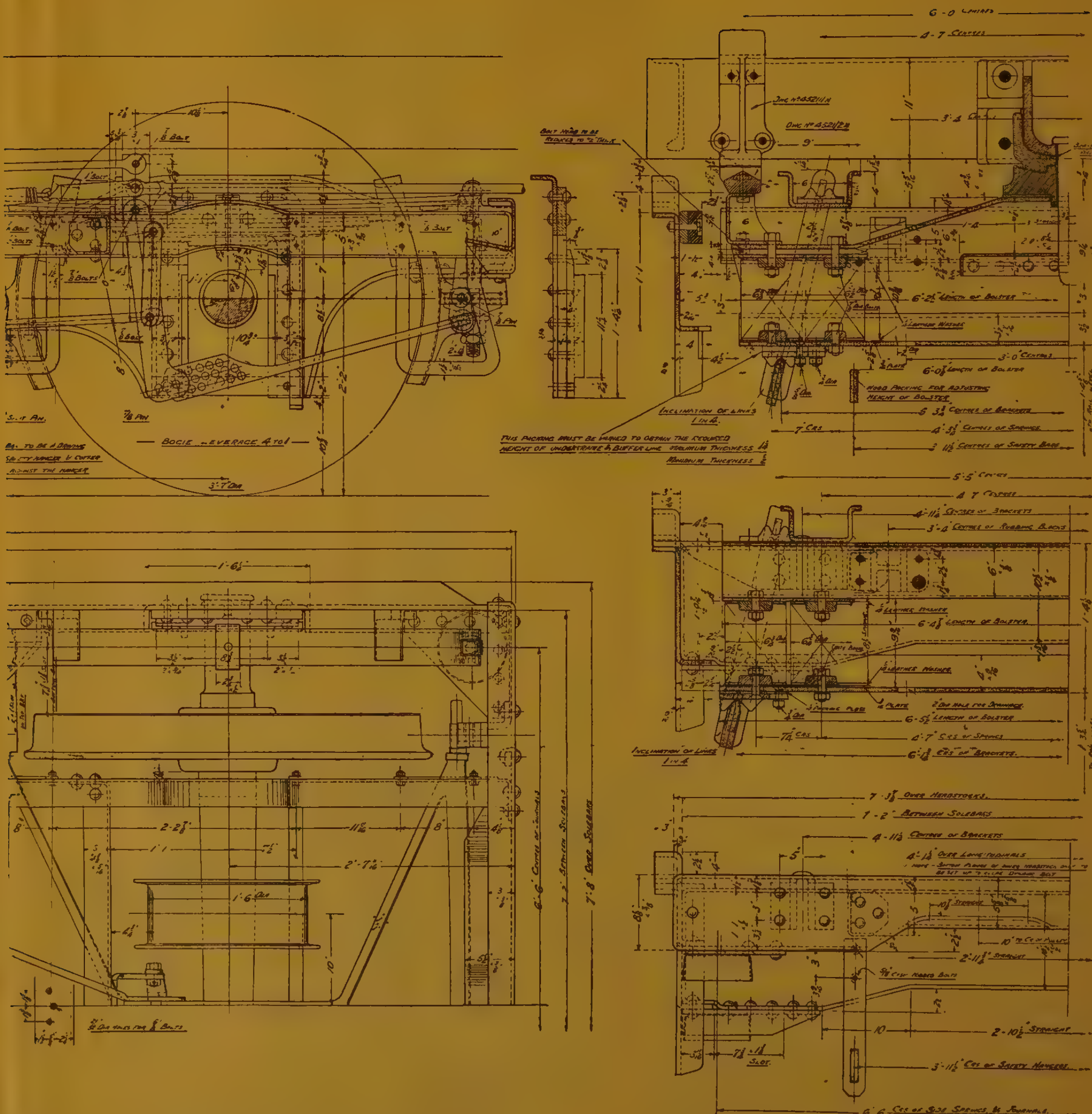


Fig. 19. — 8 ft. 6 in. wheelbase bogie — I



0-in. × 5 in. journals — 6 ft. 6 in. centres.

as the ventilators can be kept closed, the noise is much lessened.

The interior decoration of the various units introduces several novel features.

The first-class compartments, each of which seats four passengers, have been decorated in blue and fawn with chromium plated metal fittings. The walls above the seat backs are covered with blue Rexine and the ceiling with Rexine of a lighter shade. The design has been developed with the idea of making the compartments appear as spacious as possible. This has been achieved by the absence of mouldings, etc., and by arranging the chromium-plated luggage strips vertically on the partition instead of horizontally as is more usual.

Fig. 20. — First-class compartment.

The interior of one of these compartments is shown in figure 20.

The sliding doors are of a new design to give a better outlook to the corridor, and are fitted with a new type of Kaye lock specially introduced for the purpose: this door is shown clearly in figure 21.

The seats are upholstered in Firth's silver and blue broché rep, Vi-spring seat fillings being used throughout. The

Fig. 21. — Third-class compartment.

hinged centre armrests, the side armrests and the headrests have fillings of Dunlopillo rubber. Loose feather cushions in blue silk are also provided. Each window is provided with a blind of blue Rexine, while silver and blue silk curtains are fitted to each body side light.

The train is fitted with Stone's train lighting system at 24 volts. The dynamos are driven by « Railite » belts from the axles. The equipment in each unit includes Pritchett & Gold Planté batteries.

Tubular lamps are used throughout, a 35-watt lamp in a chromium plated reflector being fitted in the centre of the ceiling. Tubular reading lamps of 15-watt capacity are fitted in each corner above the seat back.

In order to improve the general lighting for reading, a large rectangular mirror has been placed over each seat back below the parcels rack. This mirror is so inclined that the light from the tubular lamp in the ceiling is reflected onto the book or newspaper which the passenger may be reading.

The floor is covered with blue cork linoleum over which is laid a blue jaspé Wilton rug.

The third-class compartments are

designed to seat six persons in each, the decorations being carried out in green and the fittings chromium plated. The fixed seats have armrests and are covered in a Holdsworth green and fawn rep. Lighting is provided by two 40-watt lamps in chromium-plated ceiling fittings. This compartment is shown in the photograph, figure 21.

The decoration of the first-class restaurant car is something quite new in railway practice. The walls in this saloon and in the open portion of the adjacent semi-open car are panelled in figured Australian maple. This panelling was manufactured by Messrs. Mallinsons to Mr. Gresley's requirements, Mr. Gresley selecting this wood on account of its striking grain and attractive colour.

The whole finish is entirely flush, the necessary decorative and architectural effects being obtained by the grain and colour of the timber without any adventitious aid from inlays, veneers of different woods, etc. The result is a well balanced and attractively finished interior, free from any unnecessary projections which might collect dust.

By carrying the cornice line above the actual cant rail line the apparent size of the compartment has been considerably increased.

Loose chairs are provided, one on each side of a centre gangway, and are upholstered in a Lee's blue tapestry with a trellis design in fawn, Vi-spring and Vito seat fillings being used. These chairs are based on a late seventeenth century chair and represent a notable advance in carriage seating.

The ceiling is tinted pale blue. The floor is covered with a sponge rubber underlay on which is placed a blue jaspé Wilton carpet specially manufactured by Messrs. Firth to tone in with the general colour scheme.

Tubular lighting is again employed in this saloon, two 35-watt tubular opal lamps in chromium reflector type fittings being fixed to the cornice above each side window. A fixed standard table lamp with a beige Nacrolaque shade is fixed to the waist rail at each table. This car is shown on figure 22, and the semi-open first in figure 23.

The walls of the third-class restaurant car are flush panelled in quartered Burmah teak also supplied by Messrs. Mallinsons, the fittings throughout being chromium plated. The fixed seats are arranged two on one side of the gangway and one on the other, and are upholstered in green uncut moquette.

The carpet in the third-class restaurant car is fawn with a black and green pattern; a sponge rubber underlay is provided.

Each section is lighted by means of one 60-watt opal lamp in the centre of the ceiling.

The centre unit of the triplet restaurant-car set consists of a large kitchen, pantry, attendants' compartment and attendants' toilet, and is equipped with electric cooking apparatus made by Messrs. J. Stone & Company. The power equipment consists of two 10-k.w. generators belt-driven from the axle, generating direct current at 220 volts, and follows in general layout the previous equipments supplied by this Company. Considerable improvements have been made in the actual cooking appliances and in the layout thereof.

Previous stoves and accessories have been built up with cast iron sections, but in this equipment the framing is of light steel sections electrically welded with a great saving in weight. The main cooking range is fitted across one end of the kitchen, and comprises a roasting oven, steaming oven, and grill, to-

Fig. 22. — Saloon car.

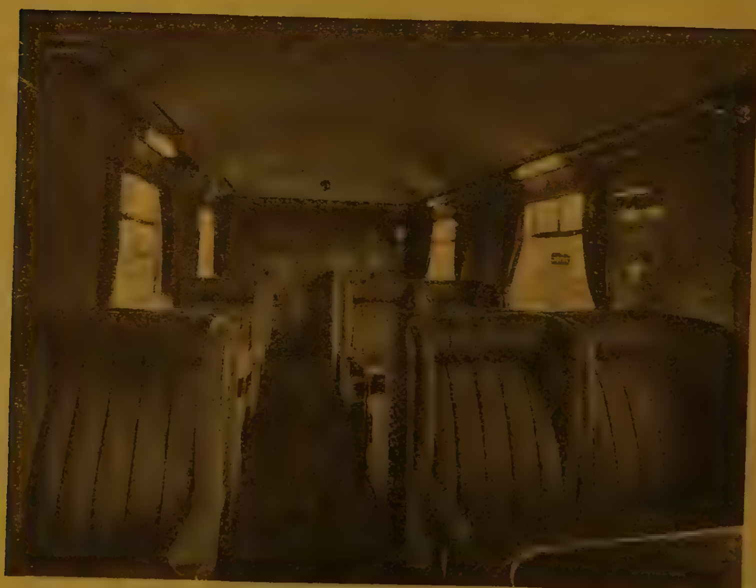


Fig. 23. — Semi-open first-class coach.

gether with a boiling table having four boiling plates. A special feature of the boiling table is that the whole of the top surface is heated and is not, as hitherto, composed of small separate heating elements. A hot cupboard has been provided on the corridor side, the top of which has been constructed to form a heated carving table with special wells for sauces, gravies, etc. An auxiliary hot water tank of 4-gallon capacity is provided for kitchen use. A fish fryer is also provided.

The loadings of the various items of equipment are as follows, the loadings being at 220 volts :

Roasting oven	4.3 k. w.
Steaming oven	3.0 »
Boiling table	12.0 »
Grill	3.5 »
Carving table	2.0 »
Fish fryer	3.3 »
Boiler	3.0 »
Automatic boiler and coffee machine	7.5 »
Water tanks in roof	12.6 »

A further new feature is the provision of sinks each having a 1-k.w. heating element clamped to the under side, to

Fig. 24. — Kitchen.

ensure that the water remains hot during the process of washing up.

The tops of the benches are covered with Staybrite steel plates.

An automatic electric refrigerator is also provided in the kitchen, together with an ice cream cabinet operated from the same unit.

The main hot and cold water tanks are fitted in the corridor roof, the former being heated by means of an electric element together with an auxiliary steam coil for use during the autumn and winter seasons.

The main switchboard is of a special type in which the bodies of the indicator

lamps and switches are enclosed, the switchboard being specially ventilated.

The kitchen is illustrated in figure 24 and the pantry in figure 25.

The pantry is provided with shelves, cupboards and racks for storage of cutlery, crockery and provisions; wine cupboards are also provided, together with a further cupboard having special racks for the storage of liqueurs.

An extension of the refrigerator cabinet provides accommodation for white wines and for butter, cheese and cream in the lower part.

Fig. 25. — Pantry.

A constant supply of hot water is ensured by the provision of an automatic boiler supplied by Messrs. Wm. Still & Co. A coffee making machine and milk urn to work in conjunction with this boiler has also been provided by the same firm and is shown in figure 25.

A Chloride Exide-Ironclad battery of 210 ampere-hours capacity is provided for use when the vehicle is standing.

Plugs and sockets are provided at terminal stations by means of which the equipment on the train may be connected to the station supply so that cooking can

be done before the train starts on its journey. The cables are removed before the train starts. In order to prevent any movement of the train while it is connected to the station supply, a valve is provided having a lever which covers the socket on the train. This valve is connected to the vacuum brake train pipe and as it must remain open as long as the cable is connected to the train the brake cannot be released. Provision is also made for charging up the batteries from the station supply if necessary.

The walls and ceiling of each toilet compartment are covered with Rexine, whilst the floor is covered with « Korkoid » tinted to match the walls. All metal fittings are chromium plated. The hopper is of the sealed type with a flushing cistern controlled by a push button. Hot and cold water is provided in all wash basins, the water being heated during the winter season by means of a steam heater and in the summer by an electric immersion heater under the wash basin. The hot water tap is provided with a red insert and the cold with a white insert on the lever in order that they may be readily distinguished. The decoration of the first-class toilets has been carried out in blue, and the third-class toilets in brown.

The locomotive and train have been built throughout at the Doncaster Works of the London & North Eastern Railway Company, to the designs of Mr. H. N. Gresley, C. B. E., the Chief Mechanical Engineer.

The train has fulfilled all expectations.

Competition by roads, waterways and airways.

(*Continuation*) (1).

France and Africa (Kenya and Uganda).

FRANCE.

The Management Committee of the French Main Line Railways has been good enough to send us the following note, relating to the first quarter of 1935. The information contained therein shows the great progress made in France in co-ordinating transport.

I. — Road competition.

A. — Co-ordination of passenger transport.
Decree of the 25th February 1935.

The Co-ordination Committee set up as a result of the decree of the 19th April, 1934, unanimously agreed the general regulations which after examination by the State Council were enforced by the decree of the 25th February 1935.

These public administrative regulations are in three parts. The last two relate particularly to passenger transport.

1. *Creation in each Département of a Technical Transport Committee.*

A Technical Transport Committee was set up in each Département in accordance with the decree of the 25th February, 1935 and, like the Headquarters Co-ordination Committee, was formed of five experts appointed for three years, representing each class of carriers concerned (main-line railways — local railways — subsidised motor transport firms — non-subsidised motor transport firms dealing with passengers — and those dealing with goods). The expenses arising from the functioning of such Committees are covered by a special tax upon the various transport undertakings.

The technical transport committees which are, in character, professionnal organisations, are independent, but work in agreement with the administrative authorities (Prefects, Regional Post Office Managers, and Bridges and Roads Departments Regional Managers) and carry out investigations, collect information, and act as supervisors for the Headquarters Co-ordination Committee.

All decisions must be passed unanimously; otherwise the case is referred to the Headquarters Co-ordination Committee and settled by it.

The technical transport committees have three duties to carry out in connection with passenger and goods transport within the Département or in some cases the region concerned :

a) to help in *drawing up agreements between transport undertakings*, endea-

(*) See *Bulletin of the Railway Congress*, June 1934 to July 1935.

vouring to get them all into the proposed schemes and to accept the bases upon which such agreements can be made.

In the case of passenger transport more particularly, the technical committees are required to reconsider and complete the agreements come to in the past in a certain number of Départements. In all the Départements they have to complete and lay before the Headquarters Co-ordination Committee the papers referring to the agreements to be entered into, or if not agreed, the negociations undertaken;

b) After the agreements have been ratified by the Ministry, the technical committees *supervise the carrying out of the agreements* (as regards rates, timetables, routes, etc...).

In the case of passenger transport the technical committees, if need be, enforce the penalties provided for by the decree;

c) Finally the technical transport committees are invested with *particular powers*, notably as concerns supervision and checking the number of motor vehicles used for public transport, a census of which was ordered by the decree of the 19th April, 1934.

2. *Provisions relating to agreements in connection with public passenger transport.*

The second part of the decree of the 25th February, 1935, lays down the general principles upon which the regional agreements made by public passenger carriers are to be based. These general principles can be summed up as follows :

a) *Co-ordinated transport.*

« All passenger transport services available to the public, for commercial objects, are to be considered as public. »

In accordance with the decree of the 25th February, 1935, these co-ordination measures do not apply to the transport of passengers carried out by any industrial or commercial firm, farmer, or private individual on their own behalf, on condition that the vehicles used only carry, in addition to the driver, persons belonging to the business in question, nor to the transport of passengers in hackney vehicles, provided that such vehicles are hired out as a whole and not through any agent, whether by the journey, distance, day, or a time-distance tariff.

All other passenger transport is to be considered as public transport, especially :

— *occasional* services for excursions, tours, or pilgrimages (the regulations concerning which are, however, very relaxed);

— *periodic* services on holidays, fairs, and markets;

— vehicles hired out at a price per seat and to the first fare (taxis working certain regular routes in the suburbs of large cities, particularly Paris).

b) *The working of co-ordination.*

The object in view is to do away with duplication which is a burden on the public finances, and the national economy.

For this purpose, in each Département, the main-line and local railways and the subsidised motor transport firms report to the technical transport committee as to any of their lines, whether subsidised or not, they propose to close, either wholly or in part, in view of the greater advantage of other methods of transport, after having considered the traffic and the financial results of operating the line in question. The unsubsidised motor transport firms, on their side, advise the technical committee which of their lines,

if suppressed, would justify claims for compensation.

In actual fact, the decree of the 25th February, 1935, which based co-ordination upon professional agreements between the carriers concerned (or rather between those who carried out transport services before the law of the 19th April, 1934 laying down the principle of co-ordination came into force) has laid down the principle that « the suppression of road services may involve compensation ».

As a rule such compensation (clause 12 of the decree of the 25th February 1935) consists in reserving to non-subsidised road transport firms the operation of lines formerly worked by a railway or a subsidised motor firm.

In addition, it is laid down that if a transport firm can show good reason for refusing to adhere to the agreement on account of the loss suffered through the distribution of the traffic made according to it, the whole of the carriers of the Département shall compensate him.

The services allotted to road hauliers in compensation for suppressed services, and accepted by them, shall be operated by them at their own risk.

In exceptional cases the arrangement can be reviewed within six months, but only when the operation of the service has brought to light some error in the estimated value of the compensation.

c) *Clauses safeguarding the allocation of the traffic.*

Duplicate services may have to be maintained over some routes. The decree of the 25th February 1935 provides in such cases safeguards when dividing up the traffic :

— The rates of the non-subsidised motor firms must exceed the price of railway tickets of the lowest class; if the non-subsidised firm duplicates a motor service who has an agreement with the State, Département, or Commune, its rates must not be less than those of the latter;

— the number of services and the timetables of non-subsidised motor firms will be fixed according to the distribution of the traffic;

— lastly, non-subsidised motor firms may be forbidden to operate over sections they would have to use in common with other services, especially in the case of routes already served by tram or omnibus services, in towns and their suburbs.

d) *The railways' subsidiary motor companies.*

The main-line railways, within three years from the date such agreements come into force, will cease to participate either directly or indirectly in any road transport undertakings.

3. *Obligations imposed on public passenger motor transport services.*

a) *Tariffs.*

The decree of the 25th February, 1935, provides that in the case of passenger and luggage tariffs, maximum and minimum rates shall be laid down in the agreements for each line or group of lines and be sanctioned by ministerial orders approving and putting them into force In addition, provision is made for the whole procedure to be followed (publication, time limits) in drawing up or modifying passenger rates under the supervision of the technical transport committee.

b) *Routes and timetables.*

The routes and timetables must be specified in the agreements and can only be modified with the assent of the technical transport committee.

The timetables must be posted up eight days before they come into force, be communicated to the administrative au-

thorities (Prefects and Regional Postmasters) and be drawn up, if need be, according to the clauses safeguarding the traffic distribution.

The railways and connecting public motor services must give each other fifteen days' notice of any change in their timetables.

c) *Safety of public motor passenger transport.*

Vehicles used for public motor passenger transport services are only allowed to run when carrying the special violet card indicating that they are in good mechanical order as the result of the bi-yearly technical inspection to which they are subjected.

Public passenger motor carriers are also required to insure their vehicles with an Insurance Company approved by the Ministry.

Finally, the driving staff comes under the 1919 law on the eight-hour day, and in addition has to be medically examined at regular intervals.

d) *Postal services.*

Passenger motor transport undertakings have to carry the mails under the conditions laid down in the decree (Clause 31).

e) *Guarantees and penalties.*

Public passenger motor transport firms are obliged to make a deposit in various ways.

In addition to making sure they are carried out, the agreements contain penalty clauses. These are warnings, fines, and finally the exclusion from the agreements with loss of the deposit, which debars the offender from operating any public passenger motor transport service.

The penalties have to be agreed unanimously by the technical transport committee and provision is made for their application by prefectoral order, or if an unanimous decision cannot be reached, by the Minister of Public Works after consultation with the Headquarters Coordination Committee.

f) *Duration of public passenger transport agreements.*

The agreements made between transport firms will come into force on the date fixed by the ministerial decree approving them. They will all terminate on the 31st December 1940.

At the present time (June 1935) the technical transport committees have been set up in the Départements according to the procedure laid drown, and a certain number of them have already held their first meeting and elected their President. Their task will be easier in the some 25 Départements in which the transport firms concerned have already come to some agreement.

B. — **Co-ordination of goods transport.**

Co-ordination of goods transport during the first quarter of 1935 was very thoroughly investigated by the Headquarters Co-ordination Committee with a view to drawing up general regulations for goods transport on lines similar to those of the 25th February 1935 regulations on passenger transport. The representatives of the different carriers belonging to the Committee could not come to any unanimous decision and the question is now (June 1935) before the arbitrator attached to the said Committee.

II. — **Competition from waterways.**

During the first quarter of 1935, no new general agreements were made in connection with navigation. The three

agreements already made in the case of the Rhône, the Lower Seine, and the canals in the Midi were examined by the Headquarters Rail and Water Co-ordination Committee. The first two were approved and submitted to the Chambers of Commerce concerned. The third was sent back to the Regional Commission for further examination to see if it would be possible to bring in the inland navigation firms still dessenting from it.

. The Headquarters Committee in addition has dealt with :

— authorisations to be granted by the Minister in pursuance of the decree of the 15th May 1934 (registration of new boats, transport of various kinds of goods, utilisation by third parties of boats belonging to commercial and industrial firms);

— the protection of inland boat builders;

— the question of chartering which was the object of the public administrative decree issued on the 8th June 1935, which will be considered in greater detail in the next note;

— the examination of the decisions of the regional commissions and of the disagreements which have arisen among them.

The Headquarters Co-ordination Committee has in particular passed a certain number of agreements made by the regional commissions in the case of special kinds of traffic, particularly :

— the transport of coal from the Nord and Pas-de-Calais Départements to Amiens, 75 % of which has been allocated to the railway and 25 % to inland navigation;

— certain transport of flour to Paris, divided up equally between rail and water;

— the transport of cotton from Havre, etc...

The main difficulty at the present time, especially in the Est and Nord districts, is to make the small boat owners respect the agreements made by their representatives on the regional commissions. Consequently, the latter have devoted their energies during the first quarter of 1935 to the study of a question of more immediate efficacy and interest : railway rates likely to compete with river navigation. Distribution of the traffic is achieved by rating measures to which the assent of the boat owners is first of all obtained. Many agreements about special rates have been made in this way.

* * *

AFRICA.

Kenya and Uganda Railways and Harbours.

The information published below is taken from a letter in which the General Management of the Kenya and Uganda Railways and Harbours describes the measures taken to meet competition.

In the Colony of Kenya an ordinance enacted by the Governor in December 1932, forbade the carriage of goods by motor vehicles for reward on the principal trunk road which runs from the coast for 450 miles inland, and also on the road from the connecting point to the Tanganyika border. The regions crossed by these roads are served by the railway. The law does not apply to distances of less than 30 miles.

The ordinance, which is valid for one year, has been renewed from year to year. It has had the effect of bringing back to the railway an appreciable amount of the higher rated goods traffic.

The ordinance provides for the grant-

ing of licences in special cases, but none has been issued up to the present time. It also makes an exception in the case of farm produce carried from farms to the railway station or to the towns nearest the centre of production.

In the Uganda Protectorate similar legislation has been introduced and forbids the transport by road in motor vehicles for reward between the places shown on the map attached to the ordinance. It has been found completely efficacious in protecting the import traffic, which is the chief consideration.

On Lake Victoria the Administration operates the steamer, tug and lighter services, and suffers from the competition of native dhows. These can use small ports inaccessible to the Administration's large boats. The latter has been able to come to an agreement according to which the dhows are used as feeders to its regular services. At the same time the tug and lighter services have been developed.

[313 : 625. 2, 621. 138.5 & 625. 26]

Statistics and the economical working of railways.

An investigation into the maintenance of rolling stock,

by Dr. Fr. LANDSBERG, VDI, Reichsbahnoberrat, i. R., Berlin.

General considerations.

* * *

In the modern meaning of the term, the economics of operation involve the detailed knowledge of the particular conditions of the service as well as of their interrelationship in regard to working, organisation, and economic value, so that the factors affecting the running of the service may be controlled methodically in order to get specified results.

This means perfect knowledge of all phases of the service in all its branches and at every stage. Numerical data, and their derivative, statistics, provide the instrument used for a scientific investigation into the working.

Rationally conceived, statistics must enable us:

to ascertain the laws which control the working of the undertaking;

to take the measures this information shows to be necessary;

to follow up the effect of such measures.

The compensating effect of large masses of numbers must be remembered and be limited as much as possible, if we are to appreciate causes, by handling the figures judiciously. For this purpose the data are divided up:

into *local* classes in which the presumed conditions are of the same nature for the investigation considered, and

into *logical* groups the delimitation of which removes the proposed investigation from any disturbing influences.

In addition the same effect should be represented in causes of different kinds.

In every undertaking the most important number, namely the *result* represented by *the ratio of the receipts to the expenditure*, becomes, on this basis, the starting point of the financial considerations on the one hand, and on the other the proof of the effect and rightness of the steps taken. The analysis of the figures for the whole undertaking leads us to contrast the *cost price* of the different products and groups of products with the realised or realisable *sale price*.

These general principles also apply to

railway statistics. The special nature of railway service, however, owing to the special characteristics of its product — transport — gives rise to new considerations, and also to an operating practice which differs from that of industrial undertakings. We will consider this point in the first part of the present article, so as to ascertain the possibility of using statistics in a commercial way in railway working. We will then endeavour, in the second and third parts, to illustrate this use by applying it as an example to « the use and maintenance of rolling stock ».

I. — Systematic use of statistics.

Railway statistics are the result of having to account for *the plant and its value*, the *receipts* and *expenditure*, to supply information on the nature and extent of the products of the undertaking, i.e. the *traffic worked*, and finally to show by means of what *work carried out* the traffic was handled and the financial result obtained.

To this day railway statistics are built up on these five pillars. Each vertical column has its origin in numerical data furnished by the various installations and partial operations which then follow up the organic structure of the railway as a working, steadily increasing in collective value. For the railway manager who is conversant with the statistics and their origin, this processus requires no further explanation. Examples of certain phases merely mentioned here are given when describing the use of statistics. The total plant, both fixed and rolling, the receipts and the expenditure, are indicated in quantities and in value, the operations in quantities.

The *use of statistics properly speaking* is not limited to considering the initial (absolute) numerical data; in principle it depends upon the determination of ratios which being independent of the numbers from which they are derived, enable us to make comparisons between different periods, different parts of the organisation and different undertakings. These ratios are necessary to meet the above mentioned conditions governing the statistics. They can only be used as a critirion if the hypotheses upon which they are built are respected. We would speak here — quite generally — of the part of the social structure served by the undertaking as a whole or in part, with the special kind of the traffic (passengers and goods to be carried and the conditions under which they are to be carried) and the special nature of the service (lines, methods and means of transport), and finally the organisation of the undertaking itself.

But there are also the *economic conditions* under which the traffic has moved to be considered. These are characterised within the limits of the railway statistics by the volume of traffic (taken as a whole and classified from different points of view) that is to say by the initial (absolute) numbers.

1) For *use to the first degree* the ratios are obtained from the figures in the vertical columns. In this way we ascertain the extent to which the various installations, receipts and expenditure as well as the work done enter into each of the total numbers. The expenditure is considered here from two points of view :

a) according to the class of expenditure (capital charges, including interest, amortisation, renewals; expenditure on staff and materials, both classified by employment);

b) according to the origin of the expenditure (administration, stations, loco-

motive running, maintenance, classified as far as possible by service operations).

Besides the purely numerical classification we arrive at coefficients which give information on the nature of the organisations and upon the management of the undertaking and, in conjunction with the ratios mentioned above, provide a basis of comparison. The method of calculating these values is outside the limits of the present note. A few examples, selected at random, will enable the reader to appreciate the method. Ratios are established :

For the *capital account :*

of single- and double-track lines	to the total length of the system;
of the length of tunnels and bridges . . .	to the total length ot fhe system;
of the number of stations on a line . . .	to the length of this line (average distance apart of stations);
of the first cost of installations or similar organisations, for example of the stations of some size, vehicles of a certain class, etc.	to their number (average first cost).

To these must be added information on the average power of locomotives, the tare and tonnage of goods wagons, the tare and number in seats of passenger carriages, etc.

For the *traffic worked :*

the ton-miles supplied	to the tonnage carried (average distance run);
complete loads, grouped by class of rates .	to the total number of wagons dispatched;
passenger-miles	to the number of passengers carried (average journey distance);
passenger-miles	to the seat-miles (use made of the seats available).

For the *various operations in the service carried out :*

vehicle-miles and axle-miles for the different methods of operating for goods and passengers	to the train-miles (average composition of the trains);
ton-miles, gross and net	to the train-miles (total and useful weight per train);
ton-miles, gross and net	to axle-miles (total weight and useful weight per axle);
of the booked journey time	to the length of the line (average commercial speed).

2) *Second-degree use* is based upon ratios determined between parts of the different vertical columns; it shows cross relations in connection with possible variations and gives a closer check of the value represented by the denominator. The examples below, selected as stated above therefore always use as denominator values taken from the vertical column indicated in each case, and as numerator values taken from other columns. It should be noted that for

expenditure — as in the capital account — the indications are given with and without money values, so that against the staff expenditure are shown the numbers of individuals occupied and the numbers of hours worked, and in the case of materials, against the values, the quantities.

Ratios can be established :

between the *first cost* and a certain number of installations, or similar organisations, and

the receipts realised therefrom;

the expenditure necessary to maintain them;

the traffic worked, and the service given through this expenditure;

in a general way this gives the user, for example, in the case of a line, in passenger-miles, or ton-miles as density of traffic; the train-miles, vehicle-miles, or axle-miles as service density; and in addition for the locomotives, the locomotive-miles, the train-miles, or the ton-miles; for the goods wagons the axle-miles, or the ton-miles charged for; for the loading capacity, the useful load in tons, etc.

between the *traffic worked,* and :

the receipts realised therefrom,

the service operations needed to work it,

the expenditure in staff to work the traffic, for example for consigning, conveying;

the expenditure for maintaining the equipment;

between the *service carried out* and :

the expenditure on staff and materials resulting therefrom, with and without showing the value, classified according to the different service operations.

between the *receipts and expenditure,* and :

the values taken in the three other columns, as shown by a few examples quoted above.

The subdivision of the expenditure occasions much more work, as is shown below.

The ratio of the expenditure to the different operations involved in carrying out the transport and finally in the actually saleable work gives the elements of the costs which, when combined together, should show the unit cost of working the traffic (that is to say the cost per train-mile, per vehicle-mile, per axle-mile, per gross and net ton-mile, per passenger-mile, etc.) which in turn enables us to arrive at the cost price, which as we pointed out above is of particular importance, and to contrast it with the selling price (tariff).

In actual practice the simple system described above of using the general statistics is not a success for the following reasons :

The selling price (the tariff) varies with the nature of the object carried (passengers, goods, etc.), with the kind of transport used (the class for passengers, the class of wagon for goods), and with the method of transport (the kind of train). But the costs cannot be classified directly according to these points of view, seeing that the major part of the expenditure on staff and materials is common to several of the methods of production. Even the general division between passenger and goods traffic can only be made indirectly, when distributing these costs (for example as regards the maintenance and supervision of the lines, the working and maintenance of the rolling stock used in mixed services, dispatching consignments, etc.) and therefore cannot be readily calculated exactly. The selection of the headings under which the charges are divided can be assisted by scientific considerations, but it can also be falsified by arbitrary theories and opinions. The more the traf-

fic worked is subdivided in order to contrast it with the rates, the greater the number of charges used for determining the individual costs, which cannot be calculated exactly and consequently have to be allocated arbitrarily.

These numerous and difficult calculations have been made by some administrations and have proved to be extremely valuable for checking the rates and for making comparative financial calculations, for example when selecting the route to be followed, in connection with the productivity of certain lines, and also when dealing with competition with other methods of transport, etc. The only way we can establish a direct comparison between the expenditure and the receipts from the statistics is by using the totals; if these values are to be more thoroughly investigated they can always be subdivided locally, and the different periods be brought together (for the whole of the undertaking and for its parts). Here again, hypotheses are inevitable, especially if there is question of distributing the receipts between different areas jointly concerned.

***

The above review shows that railway statistics as usually established can be used in many different ways with a view to working the lines economically, but that for this purpose the cost price does not function in the same way in a classification corresponding to the selling price (the rates)—owing to the special way in which it is calculated—as it does, for example, in the case of mass production, but rather as some sort of check calculation. The result is that in railway service it is very necessary to study the individual operations along the line of production, i.e. to investigate the origin of the work done and the expenditure entailed, taking into account cause and effect, and using for check purposes the elements making up the final cost of working the traffic, so far as they have not been distributed between the different sorts of operations arbitrarily.

In connection with the use and maintenance of the rolling stock, we will endeavour hereafter to use the statistics for studying the « steam locomotives ». This test does not pretend to be complete; but it shows in broad lines by means of the statistics of several railways how to proceed and how to find the numbers which lend themselves to comparisons and conclusions. The application to other parts of the subject should not present any difficulties.

II. — The maintenance and use of locomotives as shown in the statistics.

Before touching a financial matter of this kind, the importance of the subject relatively to the whole undertaking should be ascertained, and an endeavour made to learn the financial and technical relations existing within it. Only then can the information supplied by the statistics take form and be used to get a true appreciation of the facts.

1. — The financial importance of rolling stock maintenance.

The first coefficient is *the proportion of the cost of the rolling stock to the total capital cost.* The composition of this capital is only known for a small number of railway companies : usually only the annual increases and reductions under the different stock headings are recorded. Then too the fluctuations in currency values in the post-war years has made it difficult to ascertain the true basic values. The method of giving the

rolling stock numbers, showing the value of new purchases, and calculating the momentary value from the usual life and the part of this life already passed is practicable, but involves much work and is nonetheless based on estimations. The proportion of capital represented by the rolling stock cannot, therefore, be fixed in any general way.

From the « Railway Returns of Great Britain », the va'ue of the rolling stock for the four English main-line Railways is 15 % (*) of the capital cost; according to the « Relazione dell' anno finanziario della Ferrovie dello Stato », it is 17 % for the Italian State Railways.

In any case, the vehicles represent a considerable part of the capital, and the financial importance of this part is still greater because their life is shorter than that of the other elements which form a railway.

On the other hand *the proportion of the rolling stock maintenance costs (current maintenance and heavy repairs) in the total operating costs* is generally known; it varies from 14 to 15 % with, in 1932, a minimum of 13.2 %, and a maximum of 19.3 % (in Japan it is only 8 %). Table 1 shows under (*a*) the variations of this proportion for the Deutsche Reichsbahn, the English Group Railways (in common values), and for the Belgian, French, and Italian State Railways. In the same table under (*b*) is found the part due to steam locomotives in the total rolling stock repair costs.

In the case of the United States of America, the « Statistics of Railways », 1931, show proportions which — including Pullman vehicles — are about the same. Wide variations between the proportions shown on certain railways are partly explained by the way the annual accounts are prepared; but this is a question we cannot go into here.

It is interesting to note that when electric vehicles are excluded, the remainder of the maintenance costs is divided between the passenger and goods stock in almost equal parts in Germany and England (10 : 10), whereas in Belgium (with 10 : 14.5) and the United States (with 10 : 24) the goods wagons are the more important, and in Italy, where there is much tourist traffic, the passenger vehicles (with 10 : 0.85).

In the case of steam locomotives, table 2 shows under (*a*) the maintenance costs in the currency of the different countries, and under (*b*) the comparison of these costs with those of 1929, taken as equal to 100.

The rolling stock *repair shops* absorb, according to the sources quoted above, about 1/10th of the capital invested in rolling stock, i.e. 1.5 to 2 % of the whole capital cost. The annual repair costs represent 75 to 100 % of the capital cost, whereas the ratio of the total expenditure to the total capital is only 1/7th. The shop facilities are therefore very intensively used.

The cost of repairs to rolling stock are divided almost equally between staff and materials, as is shown, for example, in the report of the French State Railways. Naturally the proportion varies in locomotive, passenger carriage, and goods wagon repairs; it also depends upon the design of the vehicles, the wages level, and the cost of materials, as well as upon the working methods. The average value however shows how large a proportion the cost of the staff and materials forms of the whole undertaking.

The *staff* engaged on rolling stock repairs represents about the same propor-

(*) According to « Railway Economics » by FENELON (London, 1932) it is only 13 %.

tion of the total staff of the undertaking as that given above for the repair costs, i.e. between 13 and 16 % (in Japan only 8 %).

To end this chapter we must point out that the maintenance of the rolling stock naturally forms a greater part of the traction costs properly speaking than is shown by the figures quoted above, and probably reaches about 20 % for goods trains and 30 % for passenger trains.

2. — The industrial, technical, and financial bases.

The amount of capital invested as well as the maintenance costs vary with the total *rolling stock*, which depends, in principle, upon :

a) the extent of the traffic and its variations;

b) the suitability of the design of vehicles to meet traffic requirements;

c) the use made of the vehicles within the timings;

d) the maintenance of the vehicles.

a) The number of vehicles to be hept ready for service is governed by the traffic variations (including peaks). The seasonal variations differ from one country to another according to climate and the economic structure of the country, and as their extent is known from the statistics, they can be counteracted by suitable rating measures. The peak loadings must be estimated by experience, in conjunction with changes in the national economy, and be used as the basis of the annual budget. The evolution which has taken place during recent years must also be taken into account, as it forms an essential factor in preparing the programme of new purchases (selection of the type and number of vehicles to be purchased).

b) When vehicles can be used for all and any purposes, a smaller stock is required than when groups of vehicles are specially designed for certain purposes. The capital will be badly employed if the groups are large and if the demands for these special vehicles is only over a short period and can be met — possibly less cheaply and less easily — by the ordinary types. This point of view ought also to receive attention when deciding to increase the power of the locomotives and the carrying capacity of the passenger carriages and goods wagons; these increases may offer advantages when the traffic is heavy, but when it is not, the motive power and the transport capacity available may be excessive without reducing the number of vehicles to be hauled, with the result that the financial efficiency of the motive power falls off.

c) and *d*) The timetable, as expressing the traffic requirements, and the stock of vehicles, i.e. the number and type, supply the basis for *using the rolling stock economically*, this term covering the use of the vehicles and their maintenance in good order.

The *user* of the vehicles depends upon the vehicles being properly selected for the different kinds of service, as well as upon their being ready in sufficient time. It also depends upon the supervision as to the suitability for the service of all the vehicles required, i.e. that they are maintained in good order. Wise allocation of vehicles to cover the workings (plan of rotation), the reduction of the time required for working purposes (including turning) repairs carried out promptly and well in the maintenance shops, the formation of a reasonable reserve of vehicles in good running order, and suitable for many purposes, are

needed to work the traffic with a minimum of stock.

The object of *maintenance* is to repair all parts of the vehicles so that when given regular attention by the services using them, they can meet requirements during a certain period. The *quality* of the work done, in conjunction with the quality of the ordinary repairs, affects the frequency with which vehicles are stopped for repairs; the *frequency* and the *duration* of the repairs affects the number of spare vehicles, and consequently the amount of stock and the size of the workshops for dealing with it.

There is therefore a very close relation between the user and the maintenance, as regards the working and finance; close collaboration between the responsible authorities is first of all necessary as concerns :

the division, as regards the time, of the work to be done on the vehicles, so that such repairs are done when the traffic is light, to ensure having the greatest possible number of vehicles available for service when the traffic is heavy;

the *material division of the work* to be carried out on the vehicles, so that the ordinary running repairs to maintain the vehicles in good order fit in with the heavy repairs carried out periodically in the main workshops, as dictated by experience and the regulations.

The distribution of the work between the outside repair shops and the main workshops varies on the railways considered here. In Germany, for example, the outside repair shops are only responsible for running repairs, whereas in Italy and France they also carry out medium repairs or periodical overhauls (shown in line 2 of the table in the following chapter). In these two countries the equipment and shop methods in the repair shops have been developed accordingly, as the central workshops have only to deal with heavy repairs, general overhauls and rebuilds.

These details of organisation will not be taken into account below, but the results obtained in locomotive maintenance will be considered as a whole. Considerations of principle show that the two services, user and repair, both contribute their part in the final result.

III. — The results according to the statistics.
(Steam locomotives).

The statistical results should be considered from the points of view from which the maintenance and use of the locomotives have been methodically developed in recent years on all railways. These points of view are the following :

A. *Intensified use* of the locomotives;

B. *Systematic* locomotive maintenance;

A and B. *Common measures.*

The characteristic ratios by means of which we propose to show the development in question depend upon the nature and the size of the undertaking. It is therefore necessary, when dealing with them, to take into consideration :

a) the nature, varying with the service, of the mileage run by the locomotives, represented by the proportion of the locomotive-miles run on express trains, on ordinary passenger trains, and on goods trains, assisting or pushing service, light engines, station shunting, and other miscellaneous mileage;

b) the volume of work done during the period considered, represented by the total number of locomotive-miles run.

a) If we take the average locomotive mileage per unit of time or per locomo-

tive, the nature of the runs made is very important. We must not loose sight of the general practice to reduce the accessory mileage of the locomotives relatively to the useful mileage, so as to make better use of the engines, but on the other hand, because of the financial crisis, the goods traffic, i.e. the influence of slow trains has diminished more appreciably than the passenger traffic with its faster trains. In comparing the different countries the difference of the ratio of the classes of trains between themselves has considerable importance as regards the mileage.

In table 3 below for simplicity only the proportion of useful locomotive-miles in passenger and goods trains in terms of the whole of the locomotive-miles [in (*b*) and (*c*)] as well as the total number [in (*a*)] is shown. The remainder, that is 100 — $(b + c)$, continues to decrease steadily not only because it includes station shunting which may be up to 100 % of the useful mileage of goods trains, but also through the successful reduction in the locomotive accessory mileage.

On all railways — with the exception of F (France) — the proportion of goods train locomotive-miles has fallen in favour of that of the passenger train-miles, which would seem to indicate that the increasing effect of faster trains will produce a greater average annual locomotive mileage.

b) The use made of the locomotive can only be judged in connection with the *general situation*. It is clear, in fact, that it is much easier to plan an economical organisation when it is possible to foresee the evolution of the position, and the more stable this is. In addition it is possible to work the more economically the denser and the more varied the railway service is, because it is then easier to balance the different demands. In the running and repair services, the need for forming a reserve of engines and staff introduces circumstances comparable from an economical point of view with the fixed charges which increase in amount and harmfulness as the volume of traffic falls. For this reason, in all subsequent appreciations the fact that the total number of miles run by the locomotives has steadily fallen off in the years considered must be allowed for [Table 4 under (*a*)]. Against this, the load hauled has become greater and a better use has been made of the power of the locomotive following the improvements in the locomotives. The highly industrialised countries, such as Germany and Belgium (in England only the gross ton-miles are known) are an exception to the rule as the gross ton-miles have fallen off more seriously than the locomotive-miles. Germany, however, showed in 1933 an increase in the gross ton-miles, whereas the locomotive-miles continue to fall.

We can now consider how we are to see that the rolling stock has been used economically.

A. *Increase in the user.*

Before any judgment can be formed on this question, the use made of the locomotive stock and the results obtained must be examined.

From the stock position we find first of all the number of locomotives out of service, as surplus to requirements; it is most important financially to decide the stock really necessary for the service and to adjust it to the volume of traffic as the latter falls off. Otherwise there is the possibility of having an excessive number of locomotives, and of different types, which leads to the individual lo-

comotives being badly used and an unnecessarily high number being repaired. The classes uneconomical in service and maintenance under the new traffic conditions are now withdrawn from service. First it is considered good practice to use them until they are no longer suitable for the work or until due for a periodical repair, so as not to incur repair costs uselessly (especially as after having been out of service for some time, they must still be passed through the shops before being used).

Part of the stock really required is fit for service and part is stopped for repairs in the main shops and running sheds. Such data are reproduced in the form of annual averages (arithmetical average of the days stopped).

The number of locomotives really in use, including those which are in regular reserve, is a most important figure in this investigation. These engines are designated by the terms « benutzte », « in use » or « in traffic », « en service journalier ». The number is generally found by dividing the time in service (days or hours) by the total time. The ratio of this number to that of the locomotive-miles will give the coefficient of locomotive use (= annual distance run by a locomotive in regular or daily service).

When this number has not been calculated for each class of train, and is the average value, as in our case, the differences in the kinds of trains run, as shown in table 3, must be taken into account. The coefficients are shown in table 5. The general tendency towards better utilisation is all we are able to show. No comparison can be made between the different railways, because the basis of the calculations, especially the number of locomotives considered, is possibly different. Some railways have supplied the coefficients themselves; in some cases we have had to calculate the number of locomotives in service, and the number obtained may be rather too great and the mileage indicated too small through insufficient data.

A remarkable kind of *coefficient* showing the use of locomotives is given in the British *Railway Returns*. The use is classified:

by *time*, shown by the engine-hours in traffic per day and per engine in use, and

by *distance*, shown by engine-miles per day per engine in service.

The two coefficents are given separately for weekdays and for Sundays. The general considerations developed above show that the first coefficient (weekday) has declined through the crisis (1929: 12.07 hours; 1932: 11.08 hours), whereas the second has increased, mainly because of the higher proportion of fast trains (1929: 100.02 miles; 1932: 102.99 miles). These remarks only apply of course to the averages for the four companies. If considered separately the variation differs because the ratio of the mileage of passenger trains to that of goods trains has changed differently.

In addition, other coefficients given are mainly affected by changes in traffic conditions, namely the ratios of the train-mileage to the train-hours and locomotive-hours, goods trains and passenger trains being dealt with separately. At the same time, these numbers are a valuable additional method of appreciating the coefficients of the use made of the locomotives.

B. *Systematic repair work.*

There are two main aspects to be considered:

The *organisation of the repair work*, covering:

the definition of the kind of damage for the machine as a whole and for its component parts;

the preparatory work of getting out the work programmes and distribution (including the tools and equipment to be used);

the detailed inspection of the work and passing the repaired locomotive for service;

the control of the industrial result (quality of the repair) by means of notes on the nature of the defects, when they were repaired, the time in service, and the mileage, since the last repair;

the control of the financial result by means of notes on the total repair costs during one maintenance period, i.e. during the time that has elapsed between two repairs relatively to the mileage run in this period.

The above is an essential condition and a basis for the second main aspect, the *systematisation of the return* of the engines to the works, according to the time and nature of the repair.

Whereas formerly locomotives were brought into the shops when, from observations in service, they were found to be unsatisfactory as for example owing to excessive fuel consumption, a programme is now got out which prescribes for each engine, according to its class and the nature of the expected mileage, and the district in which the engine runs, the mileage after which a repair of a given kind is to be carried out. Naturally all legal and other safety regulations are complied with.

The carrying out of such a plan, and at the same time the result of systematic maintenance as a whole, can be followed by the statistics, on the average number of repairs of all kinds carried out, the average time and mileage between two repairs, and the average repair costs over this period.

To start with, the types of repairs given on the railways in question must be defined, and the names used by the said railways. As detailed information on the extent of the operations is rarely given, and as the organisation differs, an approximate agreement is all that can be expected. The types of repairs shown along the same line in the following table probably correspond to one another.

Kind of repair.	*Germany.*	*England.*	*France.*	*Belgium.*	*Italy.*
1	Hauptuntersuchung.	Heavy repair.	Grande réparation.	Grande réparation.	Riparazione con rialzo — Grande media.
2	Zwischenuntersuchung.	Light repair.	Levage.	Moyenne réparation.	
3	Zwischenausbesserung.	—	Révision intermédiaire.	—	Riordine.
4	Betriebsausbesserung.	Running repair and shed examination.	Revision dans les dépôts.	Revision dans les dépôts.	Riparazione importante o piccola.

1) *Coefficients of the frequency of repairs.*

To find this coefficient, the ratio of the number of repairs to the number of locomotives in use is calculated. The result is entered in table 6. This calculation ignores any transfers as between spare locomotives and those in service. The increase in the frequency can therefore indicate that a greater number of locomotives has been withdrawn from the reserve, sent to the shops for repairs, and then returned to reserve, so that the

average age of the latter has been reduced, or in the inverse case increased, as we showed in the April 1934 number of the English edition of the *Bulletin of the International Railway Congress Association.*

We will deal with other uses of this coefficient later on under heading (3).

In the case of railways which include No. 3 repairs in their programme and publish numerical data on the subject (Germany, Italy), table 6 gives a coefficient of 1.20; in other words 120 % of the engines shopped have received a No. 1, 2, or 3 repair. In the case of the four English main-line Companies, the average has fallen during the last five years from 98 to 93 %, evidently as a result of No. 3 and 4 repairs not being shown (and therefore not revealed by the statistics). The ratios of heavy repairs to intermediate repairs have remained almost the same for all the companies taken together (1.06 in 1928 and 1929, 1.045 in 1932); they have varied so much between the English railways, however, that they would have to be studied in detail and not in averages. The French State Railways started, in 1931, to give an intermediate repair and the coefficient changed from 65 % to 86 % in 1932. In Belgium the figures given as to No. 1 and No. 2 repairs only enable us to get a coefficient of 70 % in 1932, and 65 % in 1933.

The Reichsbahn gives figures of its repairs programme in the annual accounts (for example in 1933 the ratio of No. 1 to No. 2 repairs has become 1 to 1 as desired), as does Kühne in his work « Erhaltungswirtschaft » (Economics of maintenance), Berlin 1933 and his articles in *Die Reichsbahn.*

As regards Italy, readers are referred to the remarkable comments given in the reports on the 1931-32 and 1932-33 workings, as well as FANELLI's article in the *Rivista tecnica delle Ferrovie Italiane* of the 15th November, 1933, and in the case of France, the report on the 1932 working, page 126.

If the rhythm as regards time of the different classes of repairs is to be known, they must be shown separately with their numerical values, as is almost always done for No. 1 and 2 repairs, and is now being done in France and Italy for No. 3 repairs.

2) *The results from a working point of view.*

These results are checked from the mileage between two repairs. We will examine under heading (3) the relationship with the annual mileage, limiting ourselves for the moment to explaining the different ways of arriving at and subdividing these two mileages.

The *annual* mileage is calculated from the total mileage and the number of locomotives employed, and so can only be subdivided among the kinds of service (express trains, ordinary passenger trains, goods trains, etc.) so far as the locomotives are used exclusively for one class of service, and therefore can be shown against the corresponding number of miles. Unlike this calculation of averages, the figures of time and mileage between two repairs are taken from the records kept for each locomotive and consequently can be grouped by classes of locomotive and by kinds of working so far as the engines are used exclusively for one single kind of working, with a view to ascertaining the average values. This point is important because here again the number of classes of locomotives and mixture of kinds of work decide the average value (see comments on table 3). In table 7 we only show the average values because they are known for all the railways (England excepted).

For internal purposes, the Reichsbahn

gets out the average value for the different classes, as KÜHNE describes on page 453 of his book « Erhaltungswirtschaft » (locomotive history cards and their use). The average value for all classes and all kinds of working is the only one published, as is also done by the French State Railways. On the other hand, Italy gives the « percorrenza fra 2 riparazioni » (mileage between two repairs) for 6 kinds of workings and the general average, while Belgium adds the estimated results as given in the programme.

The British railways do not give any information on this subject (*).

In order to show the line of evolution for these companies as well, we have calculated from the numerical data published for the four companies, the average mileage between two repairs (1 and 2 together) in the following way: we have found for two consecutive years the average annual mileage from table 5 and for the third year considered the ratio—engines in use : heavy and light repairs—. The product of the two values probably represents approximately the mileage between two repairs. As the numbers of No. 1 and No. 2 repairs are about equal, the mileage between two No. 1 repairs ought to be about twice the value obtained.

Table 7 shows that the coefficient of the result obtained in service generally speaking increases so that the number of No. 1 and No. 2 repairs ought to fall proportionately. In order to safeguard the position both as regards repairs and service, intermediate periodic repairs such as No. 3 are given after a certain time or mileage.

3) *Relation between the mileage « per annum » and « between two repairs ».*

The use of the statistics, especially in connection with the period between repairs (time rhythm), to obtain data on which to get out the programme, requires some further comments on the actual results.

The mileage data relating to the mileage between two repairs is calculated accurately, as it is compiled from the notes recorded for each locomotive. The same remark applies to the theoretical annual mileage which is based on the numbers of locomotives known to be in use. This last value, it is true, can be taken as a broad measure of the service use of the locomotives, but it must be remembered that the number of locomotives used includes individual engines which are changed, so that each of the locomotives runs a lower mileage than the coefficient appears to indicate. The number of locomotives involved depends upon the strength in spare engines, which varies widely, and this is the reason why we took the number of engines used as the starting point.

It is impossible, therefore, to establish any direct relation between the mileage run in one year and that between two repairs, with the object of finding out how many times and after what period on the average the engine is brought in for repairs, but the number of locomotives concerned must be taken into account at the same time.

The following example shows this by figures selected from the statistical returns :

Let us suppose the number of locomotives available for use includes as reserve, for peak loads and unexpected demands, some 12 % of the total stock of engines against 88 % in service or a surplus of 12/0.88 % = 13.7 %.

The average mileage given by the statistics includes mileage run by locomotives awaiting periodic repairs. If we start from

(*) Our information is from the *Railway Returns;* we have no knowledge of the different companies' own reports in which probably further information is to be found.

a No. 1 repair involving six weeks out of service and a year later a No. 2 repair requiring four weeks, and if two weeks are required for a No. 3 repair in each of the two years of a maintenance period, the total loss is $6 + 4 + (2 \times 2) = 14$ weeks, or over the two years $14 \times 100/2 \times 52 = 13.5$ %, corresponding to an addition of $13.5/0.88 = 15.3$ % in the number of locomotives in service.

The annual calculated distance run by the locomotives in service, therefore, is distributed over a surplus of $13.7 + 15.3 = 29$ %. Instead of the distance amounting to 58 000 km. for example, it would only be $58\,000/1.29 = 45\,000$ km., for each individual engine concerned. If the distance run between two repairs were fixed at 56 000 km. (the number of No. 1 and No. 2 repairs being taken as equal) the repair period is $56\,000/45\,000 = 1.24$ years counted from going into service after a No. 1 or 2 repair until it is again returned to service after another such repair, i.e. including time out of service for repairs. Each engine in the group to be maintained would have to be given a No. 1 or 2 repair on the average about every 15 months. If 15 000 such repairs were given in a year, they would have to relate to a stock of $15\,000 \times 1.24 = 18\,600$ locomotives to cover the working.

In addition to the numerical ratio between the annual mileage and the mileage between two repairs, this example provides bases for appreciating the statistical results and for studying the programme. The programme ought to start with the locomotive workings and the desired use (annual mileage) to be made of the locomotives in service. By means of various additions (the significance of which — spare stock, period out of service — is clearly shown), we get the number of locomotives required, their average mileage, the length of a repair period, and the number of repairs to be estimated. This number multiplied by the mileage between two repairs should be compared with the total locomotive-miles (say the average for the two preceding years) to make sure that the miles corrected by the repairs correspond to the service mileage (*). In this case, and generally when using the calculations in practice, the changes in the locomotive stock by new engines added, by engines scrapped, or by engines put into reserve, fit or not fit for service, and in addition alterations in the traffic as regards the kinds of service and the timings, must be taken into account.

The calculation is simpler and more certain when the *average length of a repair period* is known. This can be ascertained from the notes kept for each locomotive as regards its mileage between two repairs. Nonetheless the method of calculation given above retains its usefulness in each case, as it provides a means whereby the details of the economical working of the locomotives can be ascertained.

4) *The economic results.*

The repairs of the locomotives are a factor of the traction costs and are closely connected to the other factors : capital charges (number and value of the locomotives), staff expenditure, and consumption of stores (fuel, water, lubricants). Information on many of these factors is to be found in the published returns so that it is quite feasible to build up the average traction costs (**). We will deal here with repairs only.

An increase in the mileage in a year or between two repairs does not necessarily mean an economic improvement,

(*) *Bulletin of the International Railway Congress Association*, April 1934.

(**) See STUDENT : *Die Reichsbahn*, 1930, No. 25.

as the costs of each repair and the repair costs during the repair period may increase so much that the cost of the unit in service becomes higher. Some people think there is an optimum value which limits the mileage. In the case of the individual engine the limit can be found from the notes kept for the engine (see *Engine history cards*, of the London Midland & Scottish Railway, published by Homberger in « Wirtschaftsführung und Finanzwesen bei der engl. Eisenbahnen » (Ecomical and financial organisation of the English railways), Berlin 1928, appendix 8*a*; see also information given by Kühne in « Erhaltungswirtschaft », Berlin 1933 p. 453). The whole of the costs incurred during a repair period must be brought against the mileage. At the same time, it is useful to fix the length of a period, as the basis for the capital charges.

We have no knowledge of any compilation of economic coefficients of this kind. In order to compare the *service results* so far calculated over the same series of years with the *economic results*, we give in table 8 (under *a*) relatively to the gross-kilometres of the steam locomotives, the total annual repair costs of these engines as published in the statistics.

Of all the values given in the statistics this ratio expresses most exactly the real work done by the locomotives and moreover is given by all the railways we are considering, with the exception of the English. To give a complete idea of the question we also show in the same table under *b*) the ratio of the costs to the total locomotive-kilometres.

Table 8 shows a general reduction in the costs per gross tonne-kilometre. As regards the exceptions and fluctuations from year to year, it must be realised that in maintaining vehicles and locomotives all new measures introduced and therefore the introduction of systematic repairs cannot show their effects immediately, but only gradually owing to the length of the repair periods. For example, when repairs are not done during a year, the apparent saving through the increased age of the spare stock may result in high costs later on. The result is particularly unfavourable when it coincides with a falling off in traffic, and inversely can lead to a serious shortage of locomotives if it is followed by an unexpected increase in traffic involving greater demands on the locomotive stock. A broad outlook when getting out the repair programmes in view of the general economic developments is therefore required if the Traction Department is to be organised on economic lines. For the same reason, the economic results must not be considered separately, but as a whole over a series of years and in relation to the causes to which they are due.

This being admitted, the repair costs related to the gross ton-km. should be used as the check figure, the final purpose of which is to sum up the effects of the different measures taken in connection with the repairs and use of the locomotives.

IV. — Conclusion.

The following are the general conditions to be drawn from the practical example given above to illustrate the principle of the economic use of statistics.

The technical, industrial, and economic data on which the statistics are based, which for practical reasons must be respected in all the measures adopted, must remain discernable as far as possi-

ble in the compilations of numerical data, and not be rendered invalid by wrong compilation or by regrouping the numerical values.

All the values required to show the mutual relationship between the various figures and therefrom the connections and guiding ideas, must be indicated from the original figures on which the railway statistics are compiled until they are merged in the general statistics.

The statistics when properly used should enable such important questions as the effect of reorganising the working both technically and financially to be answered, that is to say, such questions as :

What has been the result of such and such a measure?

In that direction will the result of a measure introduced be seen from the available statistics?

To attain these objects as clearly as possible, we must proceed as follows :

1. *Preliminary investigation.*

We must begin by calculating the ratios which denote the economic connections of the services and enable us to see the results of the organising, working, and economic measures taken.

2. *Application.*

The values of the ratios must be selected in accordance with the investigation mentioned above.

3. *Comparable results.*

The notions on which the statistical results to be used in the investigation mentioned above are based must be clearly defined and employed in the same way.

4. *Delimitation.*

It will be found convenient to delimit the local and logical zones represented by hypotheses of the same nature for the relations to be studied in each particular case (hypotheses relating to the organisation, to the technique of the traffic, and the working) in order to show more definitely the relation of cause to effect.

* * *

Provided these conditions are fulfilled, the present statistics provide, for their use in order to get economical operation, a good basis which also lends itself to comparisons.

(See tables 1 to 8, pp. 1348 to 1352.)

TABLE 1.

The percentage of the maintenance costs

a) *for all vehicles to the total working costs.*
b) *for the steam locomotives alone to the maintenance costs of all the vehicles.*

—	—	1928	1929	1930	1931	1932	1933	—
G	*a)*	15.9	16 0	15.5	13.8	13.2	13.0	Deutsche Reichsbahn.
	b)	48.5	50.0	47.5	46.6	47.0	46.5	
E	*a)*	14.4	14.5	14.6	14.2	13.7	. .	The 4 British Group Railways.
	b)	52.0	51.7	50.7	50.6	50.7	...	
F	*a)*	...	16 0	18.6	20.0	19.3	...	French State Rys.
	b)	...	42.6	40.2	40.5	43.4	...	
B	*a)*	13.7	12.8	13.8	14.9	13.5	11.3	Belgian National Rys. Co.
	b)	46.5	48.7	55.4	51.6	52.5	54.8	
I	*a)*	...	16.9	16.4	15.2	14.9	14.4	Italian State Rys.
	b)	...	39.5	38.8	38.8	38.3	41.0	(1929 corresponds to financial year 1928/29.)

TABLE 2.

Steam locomotive maintenance costs

a) *in millions of the respective currencies, or in thousands of £ for England.*
b) *as a percentage of the basic year : 1929 = 100.*

—	—	1928	1929	1930	1931	1932	1933
G	*a*	331	361	300	232	182.3	184.7
	b	91.5	100	83	64	50.2	51.1
E	*a*	10 388	10 245	9 843	8 887	8 180	...
	b	102	100	96.2	86 5	80	...
F	*a*	...	141.7	180.9	197 5	190	...
	b	...	100	126	138	131.5	...
B	*a*	165	192	246.5	235	187.2	147.8
	b	86	100	128	121	97.5	77
I	*a*	305	257.3	249.3	209 6	184.20	177.9
	b	119	100	97	81.5	67	69.4

TABLE 3.

Distances run by steam locomotives

a) *Annual distance in millions of kilometres or miles.*
b) *Distance run by loaded passenger trains* } *as a percentage of* a).
c) *Distance run by loaded goods trains* }

—	—	1928	1929	1930	1931	1932	1933	—
G	*a)*	820	950	893	843.6	780.4	777.4	Gesch. Ber. IV*c* (Standard-gauge lines only).
	b)	39.4	39.0	41.6	43.6	46.4	46.8	
	c)	26.5	27.1	26.2	24.8	23 7	25.2	
E	*a)*	544.5	554.4	540.5	515.5	498.6	...	Returns C No. V (A) Ind. No. 1-54. (All British standard-gauge lines).
	b)	41.3	41.0	41.6	42.7	44.0	...	
	c)	25.7	26.0	25.8	25.2	24.8	...	
F	*a)*	79.6	83.2	87.8	86.8	81	...	
	b)	...	51.0	50.5	52.0	55.5	...	
	c)	...	33.0	33.6	33.1	31.0	...	
B	*a)*	99.7	107.2	103.7	93.5	82.2	85.6	
	b)	40.4	40.0	43.3	47.2	53.6	57.2	
	c)	37.2	36.6	33.7	31.9	27.5	24.9	
I	*a)*	162.9	160.4	163.2	147.3	135.7	138.7	
	b)	...	48.4	47.6	54.4	55.3	56.5	
	c)	...	33.0	33.7	26.7	26.4	27.4	

TABLE 4.

Distances run by steam locomotives

as a % compared with the year 1929 : a) *Locomotive-km.;* b) *Gross tonne-km,*

—	—	1928	1929 ∽ 100 °/°	1930	1931	1932	1933
G	*a)*	96	956.4 mill. km.	94.5	88.8	82.3	81.6
	b)	97	257 209 mill. gross tkm.	87.5	78	69.2	71.8
E	*a)*	98	886 mill. km.	97.8	93.5	90.4	...
	b)	...	...	...	...	...	...
F	*a)*	96	83.2 mill. km.	105.5	104	96	. .
	b)	95	24 000 mill. gross tkm.	106	107	99	...
B	*a)*	93	107.2 mill. km.	97.5	87.5	77.5	81
	b)	93	32 888 mill. gross tkm.	94	84.5	70.5	69.6
I	*a)*	102	160.4 mill. km.	102	91.5	84.5	87.1
	b)	...	35 698 mill. gross tkm.	104.5	96.6	87	92.5

TABLE 5.

Annual distance run by locomotives « in use ».

a) *Locomotives available for traffic (excluding those under repair and spare).*
b) *Locomotives in use.* c) *Total number of locomotive-kilometres, in millions.*

—	—	1928	1929	1930	1931	1932	1933	Sources and remarks.
G	*a*	19 003	18 957	19 388	18 232	16 473	15 449	Statist. Übers. V 441/43.
	b	17 100 ∅	17 400 (*)	16 570 (*)	15 299 (*)	13 800 (*)	13 000(**)	(*) From KUHNE, « Erhaltungswirtschaft » pp. 447 and 466. taking 90 % of *a*). (**) Taken as 84 % of *a*).
	c	930 mill. km.	956.4	904.5	850.3	786.7	783.6	
	c : *b*	54 500 km.	55 000	54 500	55 500	57 000	60 000	
E	*a*	18 724	18 880	18 592	17 532	16 737	...	Returns C No. X. Index No. 1-4.
	b	17 120	17 231	16 817	15 747	14 947	...	Returns C No. X. Index No. 1-4.
	c	538.8 mill. miles.	549.2	537.08	512.35	495.54	...	Returns C No. V (A). Index No. 1-4.
	c : *b*	50 500 km.	51 000	51 100	52 000	53 200	...	
F	*a*	3 593	3 297	3 048	3 019	2 767	...	*a*) Calculated by taking the locomotives at the disposal of the depots less locomotives being lifted at the depots.
	b	3 233	2 951	2 743	2 717	2 470	...	
	c	79.6 mill. km.	83.2	87.8	86.8	80	...	
	c : *b*	24 700 km.	28 200	32 000	32 000	32 500 (*)	32 800 (*)	This last number obtained by dividing : locom. under lifting × average time stopped for lifting / days in the year.
B	*a*	(2 702) (*)	2 905	3 126	3 051	2 927	2 769	
	b	(2 278) (*)	2 480	2 498	2 128	1 870	1 798	*b*) Taken as 90-89 % of *a*).
	c	99.7 mill. km.	107.2	103.7	93 5	82.3	85.6	(*) Figures supplied by the Administration.
	c : *b*	(43 000) km.	43 200	41 600	43 800	44 000	47 600	*a*) and *b*) Arithmetical averages of the figures for 1931-32. (*) Values only applicable from the 31-12-1928. *a*) Including a large number of locomotives standing spare in working order.
I	*a*	...	4 167	4 026	3 549	3 236	3 027	
	b	...	3 750	3 623	3 200	2 913	2 725	
	c	— mill. km.	160.57	163 23	147.5	135.9	138.8	*b*) « In daily use ».
	c : *b*	— km.	42 800	44 000	46 000	46 700	50 800	*b*) Taken as 90 % of *a*).

Applying the German ratio for station shunting (1 hour = 7 km. = 4.35 miles) the following values are obtained for c : b in km.

	1928	1929	1930	1931	1932	1933
E	48 300	48 900	49 000	50 100	51 100	...
B	(49 400)	48 900	46 700	48 800	48 300	51 600
I	...	43 800	46 000	47 200	47 700	52 000

The values given in the upper part of the table are taken from published reports.
To make them comparable the proportion of locomotive-kilometres in shunting service has to be calculated in a uniform way.
We have used the German ratio of 1 hour = 7 km. (4.35 miles).
According to the International Statistics of the International Railway Union, one shunting hour is taken as equivalent in
England to 8 km. (5 miles)
Belgium to 4 km. (2.5 miles)
Italy to 6 km. (3.7 miles)
We do not known what constant is used in France.

TABLE 6.

Number (N) and frequency (F) of repairs.

	Kind of repair.	1929 N	1929 F	1930 N	1930 F	1931 N	1931 F	1932 N	1932 F	1933 N	1933 F
G	1	11 044		8 992		6 372		3 329	1st half year.	Figures taken from KUHNE's « Erhaltungswirtschaft », Berlin, 1933.	
	2	5 506		8 297		8 991		2 970			
	3	2 699		2 601		2 580		1 600			
	Total	19 249	1.22	19 890	1.20	17 943	1.17	7 899			
E	1	8 745		8 086		7 512		7 120			
	2	8 240		8 326		7 108		6 805			
	Total	16 985	0.985	16 412	0.98	14 620	0.926	13 925	0 93		
F	1	315		385		356		300		According to the report, the number of lifts increased considerably in 1930 and 1931 in preparation for the introduction of systematic repairs.	
	2	1 101		1 331		1 399		1 004			
	3	—		—		48		810			
	Total	1 416	0.48	1 716	0.68	1 803	0.665	2 114	0.855		
B	1	643		781		697		619		450	
	2	1 124		1 227		1 065		691		708	
	Total	1 767	0.712	1 958	0.78	1 762	0.83	1 310	0.70	1 158	0 65
I	1	946		1 017		781		737		682	
	2	1 811		1 732		1 463		984		924	
	3	—		—		—		1 780		1 800	
	Total	2 757	0.735	2 749	0.76	2 244	0.70	3 501	1.20	3 406	1.25

TABLE 7.

Mileage of steam locomotives between two repairs (in kilometres).

—	1928	1929	1930	1931	1932	1933	—
G	94 600	96 000	103 000	113 000	117 000	117 000	Between two heavy (No. 1) repairs.
E	...	51 400	52 100	55 000	55 500	...	Calculated (see the text) in common for Nos. 1 and 2.
F	49 477	52 066	50 563	53 515	53 786	...	Between lifting engines at the sheds.
B	51 931	54 859	57 570	59 984	59 487	66 514	Between two intermediate repairs.
	122 063	126 964	132 360	141 537	143 251	141 412	Between two heavy repairs.
I	...	43 791	46 470	52 465	59 292	70 364	Between two repairs, including lifting.

TABLE 8.

Cost of steam locomotive repairs (in the currencies of the respective countries).

a) *per 1 000 gross tonne-kilometres.*
b) *per 1 000 locomotive-kilometres.*

—	—	1928	1929	1930	1931	1932	1933
G	*a*	1.33	1.40	1.33	1.16	1.03	1.00
	b	362	377	332	273	232	236
E	*a*	...	...	...	...	...	...
	b	12.1	11.7	11.4	10 8	10.3	...
F	*a*	...	5.92	7.10	7.70	8.04	...
	b	...	1 700	2 060	2 280	2 380	...
B	*a*	5.40	5 85	7.92	8.50	8.10	6.46
	b	1 660	1 790	2 370	2500	2 270	1 720
I	*a*	8.75	7.20	6 67	6 05	5.92	5.42
	b	1 870	1 600	1 525	1 425	1 360	1 285

Applying the German conversion factor of 1 hour = 7 km. for shunting work, the following values are obtained for b) *(costs per 1 000 locomotive-kilometres), see the remarks in table 5.*

—	—	1928	1929	1930	1931	1932	1933
E	*b*	12.5	12.15	11.9	11.25	10.7	...
B	*b*	1 465	1 595	2 110	2 260	2 080	1 585
I	*b*	1 835	1 565	1 490	1 385	1 330	1 260

[656. 211 (.73) & 725. 31 (.73)

Pennsylvania opens new passenger station at Newark, N. J.

(Railway Age.)

Closely following extensive passenger station and general improvements at Philadelphia, Baltimore, and other important points on its heavy-traffic line between New York and Washington, D. C., the Pennsylvania, on March 24, completed and placed in service the first stage of an extensive passenger station project at Newark, N. J., a city of 450 000 population at the western gateway to the metropolitan area of New York. This project, which was started in 1929, not only includes a modern passenger station, but also provides for close co-ordination with trolley bus, taxicab and private vehicular traffic to and from a wide contiguous territory, and effective and convenient transfer of Pennsylvania traffic to and from lower Manhattan.

Fig. 1. — The Pennsylvania's modern station at Newark, N. J., which co-ordinates railway, rapid transit, trolley and bus services.

The Newark project includes a new passenger station, with eight tracks and six platforms; the construction of approximately 1 400 feet of steel and concrete viaduct carrying six to eight tracks; three vertical lift bridges over the Passaic river, one carrying three tracks, a second carrying two tracks, and the third a single track; the complete resignaling of the new station area, involving a new interlocking tower with a 155-lever machine; and such other related changes and improvements as the construction of a large express buil-

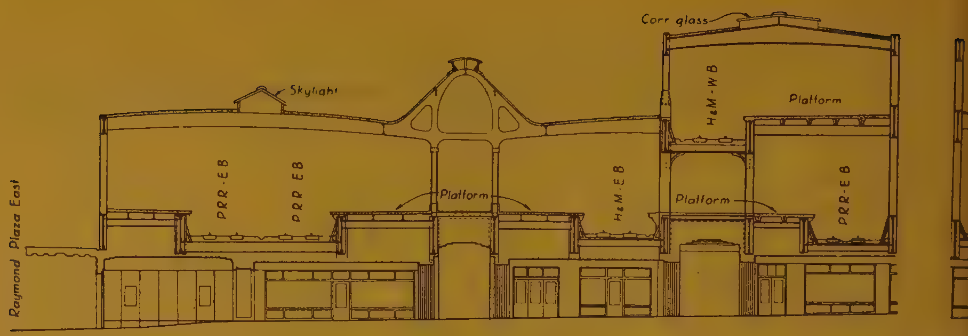


Fig. 2. — Section through the station headhouse and main concourse, looking west. — W

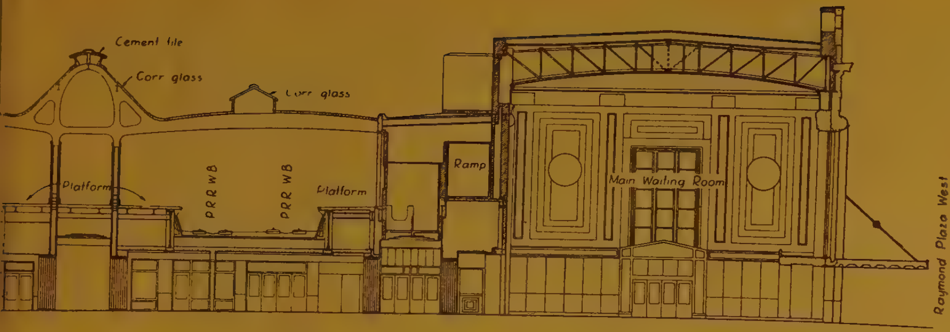
ding and the relocation and enlargement of local freight facilities. In conjunction with these improvements by the railroad, the city is widening or otherwise opening up street areas leading to and extending about the new station area, and is carrying its new trolley subway to a terminal directly beneath the station.

In the first stage of the work, which was confined in scope because of the location of the existing tracks and an old river bridge, the major facilities completed and put in service include the station headhouse with three elevated tracks and two platforms, and an adequate length of train concourse to serve the three tracks; the three-track lift span bridge, the new express facilities, and as much of the signaling and interlocking work as the present new track facilities require. All of these facilities, with the exception of the bridge, are described in this article. The remaining work to round out the complete project at Newark must of necessity await disposition of the old facilities, which, because of their extent, presents a sizeable project in itself.

Operating conditions to be improved.

The Pennsylvania passes through Newark in a general east and west direction, and in the old arrangement had four tracks, except directly through the station area, where there were only three tracks. All of these tracks were elevated on an embankment retained by heavy stone masonry walls, and were carried across streets on half-through girder bridges. The station itself, a two-story brick structure with two elevated platforms serving only the outside tracks, was located on an irregular plot of ground on the north side of the right-of-way, with frontage on Market street, one of the important streets of the city. Approximately 1 300 feet east of the station, the tracks crossed the Passaic river on a two-track swing bridge and then continued to a four-track layout at Manhattan Transfer, about a mile east of the river.

Manhattan Transfer is the point of divergence of the road's service to its main station in mid-town New York and to its station at Jersey City, N. J., and also the main point of interchange to and from the road's rapid transit connection direct to lower Manhattan via the Hudson & Manhattan Railroad. Ever since the Pennsylvania's entrance to mid-town New York, practically all passengers to and from down-town New York, via the Hudson & Manhattan, have changed trains at Manhattan Transfer, which was exclusively a transfer point in open meadow country, originating no



wn to the right is completed, while that shown to the left is still to be completed.

traffic. Beyond this point, the rapid transit trains from lower New York continued to Park Place station in Newark, a rapid transit terminal located approximately six city blocks from the Pennsylvania's Market Street station.

Until the electrification of the Pennsylvania's service from New York to Philadelphia was completed in January, 1933, Manhattan Transfer served also as the point of change between steam and electric operation, which necessitated train stops at this point. With through electric operation, this condition no longer exists and gave rise to a plan to extend the rapid transit lines directly into the Market Street station at Newark, and there effect all transfer of passengers, thereby eliminating the necessity for the extra train stop at Manhattan Transfer. This plan was incorporated in the general Newark improvement project, so that when that project is finally completed, Manhattan Transfer can be eliminated, with increased efficiency in service and greater convenience to the traveling public. This phase of the improvements at Newark, which will involve two rapid transit tracks at the new station, is still to be completed, along with a plan to extend the rapid transit tracks approximately 1 1/2 miles west of the station on an elevated structure, parallel with and directly north of the existing Pennsylvania main tracks, to a new local station or terminal at South street.

Station is attractive and well located.

In the improvements at Newark, the right-of-way, as narrow as 56 feet for a considerable distance east of the old station, has been widened generally to the north through the city, and, through the new station area, has been widened to both the north and the south, to a maximum width of approximately 240 feet. As a result, with only the necessity for cutting off a section from the rear of the old station, adequate space was afforded for the construction of three of the new station tracks and passenger platforms, while maintaining in service most of the old station and its platforms, and the three existing tracks. It also permitted the construction of the new three-track lift span bridge immediately north of the old swing bridge, so that when the first stage of the improvements was put in service, the railroad had, except as regards the number of tracks directly at the station, greatly enlarged facilities over the old arrangement.

The new station building, with taxicab space at one end and bus space and a subway trolley terminal at the other, is located on the north side of the widened right-of-way, in the two blocks immediately east of the old station. It

fronts directly on Raymond Plaza West, a thoroughfare 125 feet in width, which connects with Market street at one end and with Raymond boulevard, a new wide through thoroughfare, at the other end. In this location, the new station is much more readily accessible to vehicular and pedestrian traffic than the old station.

The station, which is a steel and masonry structure faced with gray Indiana limestone above a pink granite base course, reflects the classical style of architecture and is modern in both appearance and arrangement of facilities. It is 302 feet long by 79 feet deep, and rises to a height of 51 feet above the surrounding street level. The front facade presents a rythmical procession of square pilasters between a series of high window panels, interrupted only by two large archways of pink granite, which ornament wide entrances at about the third points in its length.

The frieze of the cornice surmounting the main facade is embellished only by a series of carved limestone panels, except directly over the entrance arches where, in each case, the otherwise plain skyline is broken by a projecting decorative motif inset with a large illuminated clock in one case and a zodiac in the other. A feature of the exterior is the consistent use of satin-finished aluminum for window frames and mullions, and as a weather-resisting ornamental covering of the broad marquees which afford protection at the entrances.

Beyond each end of the station building proper, the elevated track and platform structure, which is of structural steel with a concrete deck, is hidden from view above the deck level by a curtain wall enclosure faced with buff colored brick in attractive patterns above and below long horizontal window panels. These walls, which extend 330 feet east of the station and 575 feet west of it, are integral with graceful brick-faced arches over the portals to new half-through bridges over Market street and Raymond boulevard. As a decorative feature of these walls, limestone has been used in the coping and as trim about the windows; colorful terra cotta plaques have been inserted between adjacent window panels; and the whole is capped by a decorative aluminum cresting. The street arches are ornamented and set out by granite pylons on each side, surmounted by large carved eagles.

Interior is well laid out.

The two entrances to the station from Raymond Plaza West were provided for in keeping with one of the basic functions of the new station, which is evidenced so clearly throughout the interior arrangement — that of providing for the handling of both the railroad's patrons and the passengers of the rapid transit service to and from Jersey City and downtown New York, with the least possible interference between them. Thus, in general, the west half of the station is designed for use by the railroad's patrons, while the east half will be used largely by patrons of the rapid transit service, although the two halves of the station are in intimate contact with each other and all of the more important public facilities, including the waiting room, ticket windows, lavatories, etc., are common to both.

The main waiting room, 175 feet long by 58 feet deep, with a vaulted ceiling 46 feet high, lies directly along the front of the station, centered about the more westerly main entrance. Directly across the waiting room on the axis of this entrance, a train concourse, 45 feet wide, extends beneath the elevated tracks and gives access to and from the track platforms by means of stairways and escalators. At present, this concourse, known as the main concourse, serves only the two platforms which have been completed, but eventually, with the completion of the five additional tracks at the station, it will be continued beneath

Fig. 3. — Looking west over the station improvements, showing the first stage completed, on right, and old tracks, to be removed, on left.

Fig. 4. — Looking east through the spacious and attractive waiting room, showing the general style of architecture and interior treatment employed.

all of these tracks, a total distance of approximately 255 feet, to a street-level entrance and exit lobby on Raymond Plaza East, a new wide thoroughfare opened by the city on the east side of the railroad property.

The rapid transit portion of the station, when completed, will lie directly back of the easterly main entrance, and will consist essentially of a lobby, approximately 83 feet by 39 feet, and a ground-floor-level train concourse, 30 feet wide, which will extend beneath the tracks and afford stair and escalator access to and from the rapid transit platforms to be built later. Between this concourse and the main concourse, there will be two cross corridors, from 12 to 20 feet wide, which will be extended east of the rapid transit concourse to a bus space and a city trolley subway terminal, and west of the main concourse to a large taxicab and private

Fig. 5. — Looking east over the two station platforms completed, showing the attractive steel-frame, glass and cement tile-covered sheds to be provided generally.

car loading and unloading space. The ticket office is located on the south side of the waiting room, east of the main concourse, and has sellers' windows both on the waiting room side and on its opposite side, which faces on the more northerly cross corridor, where it can be reached readily by both through and rapid transit passengers.

Thus, it is evident that while rapid transit and through passengers will have free access to the entire building, and can move freely to any of the facilities provided, the normal movements of the two classes of patrons will not conflict. This is particularly desirous because of the large rush-hour commuter traffic that will be handled by the rapid transit service, traffic which will move rapidly through the station to or from the pedestrian entrances or those leading to and from the bus and trolley facilities.

At the present time, of course, with no rapid transit service into the station, the rapid transit areas of the station are incomplete, and a large part of the unfinished area is being used by facilities which will later be located beneath the south half of the track and platform structure. Thus, for example, the rapid transit lobby and the corridors adjacent thereto are being used temporarily for baggage-handling facilities, which, eventually, will be located beneath the most southerly elevated tracks, facing directly on Raymond Plaza East. This final location of the baggage facilities will not only provide ready access for trucks, but will confine all trucking operations to one side of the station.

The dining room and kitchen service facilities, not completed at the present time, will be located in the northeast corner of the station just east of the rapid transit entrance, and the men's and women's lavatory facilities and a barber shop will be located between the extended concourses, with access from both. Temporarily, no restaurant or barber shop facilities are provided, and the men's lavatory facilities are located di-

rectly off from the northerly cross corridor, opposite the rear of the ticket office, in space which will be used eventually as a parcel checking room.

The trolley terminal that is being built at the east end of the station, and is practically complete except for a track loop at the south end, which cannot be constructed until the old tracks of the Pennsylvania are removed, provides five tracks and five platforms, all in direct contact through stairs, escalators and sub-level passages directly with the station. The bus space, which is located directly above the trolley terminal, will provide four bus lanes and five landings, which can be reached directly from the station via mezzanine passages extending over the bus lanes.

Interior of station is pleasing.

The interior decoration and furnishings of the station are as attractive and practical as the exterior. In the large waiting room, the floor is of red terrazzo with inlaid patterns in black and yellow. Above a high wainscoting of rose yellow Travertine, quarried in Montana, the walls, except across the front face, are of soft buff-color acoustic material in panel form. In the front face of the room, the pilasters separating the high window panels are faced with Napoleon gray marble. The ceiling, which is vaulted and faced with acoustic material in a herringbone pattern, is painted a variegated blue with a series of wavy bands of gold leaf longitudinally through the center.

To relieve the otherwise plain character of the large wall expanses in the waiting room, artistic touches of color and design have been applied. For example, a series of 13 large plaster plaques depicting the history of transportation adorn the walls; satin-finished aluminum has been used widely for trim and is featured in the framing of the end entrances and in an ornate glazed vestibule inside the main entrance; and a large red panel in a marble framed arch surmounts the opening leading into the concourse. In addition, the settees, which are arranged in a series of eight rows crosswise of the room, and also along the front wall, are of walnut inlaid with aluminum trim and identification numbers, and the doors, which have wood cores, are finished with Formica of a deep red color and are provided with aluminum kick plates and a series of horizontal aluminum protection hands.

One of the most striking features of the room is the series of four main lighting fixtures suspended from the ceiling. These fixtures are spheres of opal glass, five feet in diameter, in white bronze frames, the most prominent part of which is a horizontal pierced band displaying the signs of the zodiac. These fixtures, which can be lowered to the floor for cleaning and lamp renewals, contain three groups of lamps each, permitting three different intensities of illumination.

Another feature of the room is a large sectional window over the west entrance, which has been inset with thin sheets of oil-treated Alabama marble to break the intensity of the afternoon sun and yet permit some diffused illumination. This material, which is translucent, presents a deep brilliant yellow in the sunlight, and shows in relief all of its attractive natural veining.

The waiting room side of the ticket office, which has four sellers' spaces and two information spaces, presents a marble counter, surmounted by aluminum grills at the service openings and low plate glass panels between them. On the opposite side of the ticket office, facing the north corridor between the concourses, the ticket counter, with three sales spaces, is laid out in an arc, and is entirely enclosed by glass in a bold frame of satin-finished aluminum.

The main concourse and such of the cross corridors as are completed, have a ceiling height of 10 feet and are fi-

nished with Napoleon gray marble on the side walls and an acoustic material on the ceilings. A special feature of the ceilings is their backing with a one-inch insulating blanket to deaden the noise of train movements above.

Lighting throughout the low ceiling areas is by means of recessed ceiling lamps with flat light-diffusing glass lenses set flush with the ceiling. The lighting current is 125-216-volt, 3-phase, 4-wire, 62 1/2-cycle, supplied by motor generators of 400-kw. capacity, which, in turn, are fed through transformers from the company's 11 000-volt, 25-cycle electric traction current supply lines. Three independent sources of supply are provided for, and, in addition, emergency lights are located about the building at strategic points, connected into a separate wiring system which taps the power lines used for signal operation. The power required for the operation of motors within the station, such as those driving the ventilating fans, pumps, escalators, etc., is secured direct from the railroad's traction current supply, which is passed through step-down transformers located in a masonry-enclosed room in the basement of the building. Immediately adjacent to this room is located the switchboard which controls all of the power equipment.

Special features provided at the station includes a master clock system with 13 clocks; a hold-up or burglar alarm system; a fire alarm system, directly connected with the city fire alarm system; and a pneumatic tube system, which makes personal messenger service unnecessary in conducting routine business between the ticket office and the baggage room.

The station is heated essentially by the direct method, through convection-type radiators with automatic temperature-regulating valves, which are housed within the back-to-back settees in the waiting room, and also in concealed recesses in the walls. This system is, however, supplemented by an extensive forced ventilation system which supplies a continuous flow of fresh filtered air throughout the building, which can be warmed during the cold months of the year. Steam for heating purposes is supplied by a new heating plant constructed immediately west of the site of the old station, while the fans of the ventilating system are located on the track side of the station at different floor levels. In the latter system, fresh air is taken from the third floor level on the east side of the building, and, after being filtered, washed, heated in cold weather, and humidified, is forced by fans to the various public and private areas of the station.

In the waiting room, the conditioned air is ejected through groups of slots in the center of the ceiling, and is exhausted by a separate fan system through openings provided beneath certain of the settees. This exhaust system also extends to many of the smaller areas of the station, and, eventually, will include the dining room and kitchen, the lavatories, and the taxicab and bus loading and unloading areas. Altogether, there will be a total of 10 ventilating and exhaust fans in the air-conditioning system.

Details of track layout.

Only three tracks, immediately adjacent to the station, have been completed at present, but the ultimate plan calls for eight tracks, six of which will be used by Pennsylvania trains and two by rapid transit trains. Across the station layout from the station side, these eight tracks will be as follows : A westbound station track; two westbound main or running tracks; an eastbound running track; a westbound rapid transit track; an eastbound rapid transit track: another eastbound running track; and an eastbound station track. Certain of the running tracks will be signaled for two-way operation to facilitate train movements during peak traffic.

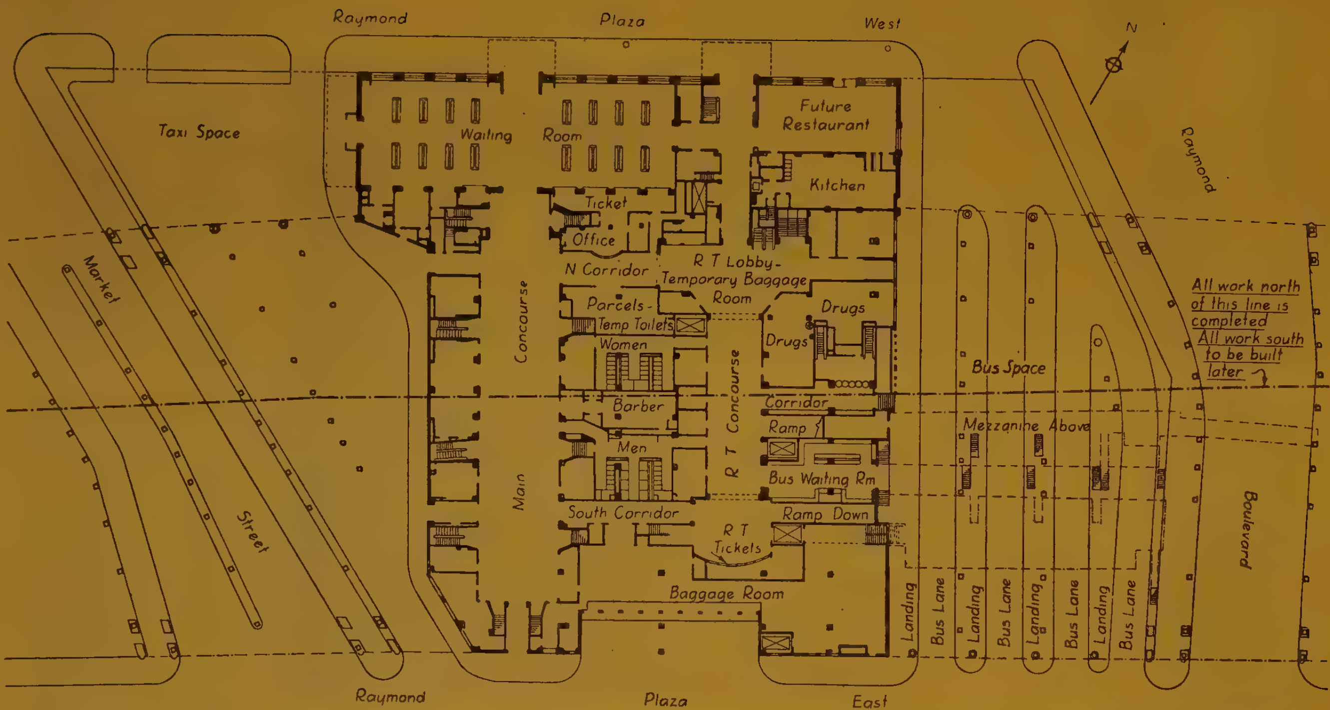


Fig. 6. — First-floor plan of the new station, showing the relation between the through and rapid transit services. Also that part of the work completed and that still to be completed.

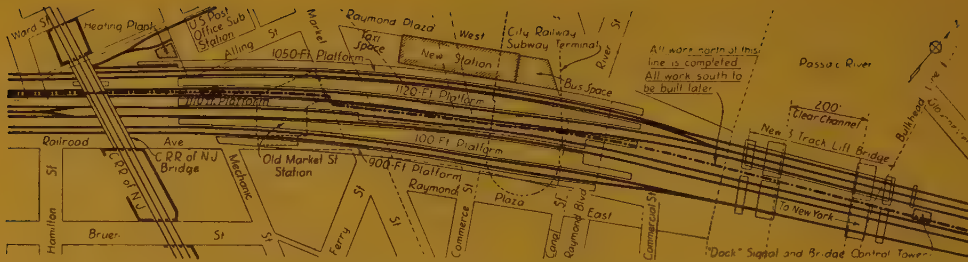


Fig. 7. — General station layout at Newark as it will be when completed. Work south of heavy dot and dash line still to be undertaken.

All of the station tracks, with the exception of the westbound rapid transit track, will be located at approximately the same level, and car-floor-height platforms will be provided to serve all tracks. A special feature of the track and platform layout is the fact that the westbound rapid transit track will be located approximately 20 feet above the level of the other tracks, and will extend longitudinally above a platform which will be continuous between one of the Pennsylvania eastbound mains and the eastbound rapid transit track handling trains to Jersey City and lower New York. With a similar platform on the opposite side of the eastbound rapid transit track, this will enable eastbound Pennsylvania passengers, destined to lower New York, to transfer from through trains on either of the main eastbound tracks, to eastbound rapid transit trains, by movement directly across a platform.

The high-level westbound rapid transit track will be served by a long car-floor-level platform on its north side, directly above a part of the platform beneath. This platform will be joined with the station proper by a wide enclosed passageway extending across the intervening tracks, with ramp connection to the westbound through platforms for the use of westbound rapid transit passengers from New York, transferring to westbound Pennsylvania trains. Westbound rapid transit passengers for Newark will use the high-level cross passage to the station, from which stairs and escalators will carry them to the ground floor level in the rapid transit portion of the station, in immediate connection with the main pedestrian exit on the Plaza, and exits to the trolley subway and bus space. Eastbound rapid transit passengers will use the ground floor rapid transit concourse directly to the escalators and stairs which will be provided to the eastbound rapid transit platform at the general track level. Thus, it will be seen that, when completed, the new station will provide for complete co-ordination of rapid transit and Pennsylvania services, with minimum conflict between patrons making separate use of these two services.

The three tracks in service at the present time, which provide trackage equivalent to that formerly at the station, will be used exclusively by Pennsylvania trains, the middle track serving for movements in either direction as the need may require. In conformity with the ultimate plan for all of the tracks throughout the station area, the tracks already constructed consist of 131-lb. rail resting on short treated ties set directly in the concrete deck of the steel viaduct structure. This construction, with its ready adaptability to cleaning, insures a tidy track structure

at all times. Hose boxes have been provided at intervals of 100 feet along the platforms to facilitate washing down the platform surfaces and the deck structure.

The three tracks completed are served by the new permanent-platform adjacent to the station building, and by one of the permanent wide island platforms. The former platform, at its extreme west end, will also eventually serve a Pullman car storage track, where originating westbound Pullman cars will be made up and be held. Both platforms, which are more than 1 000 feet long, are typical of the remaining platforms to be built in the later stages of the work. They are of reinforced concrete construction supported by the viaduct steelwork, and are covered by attractive glass and cement tile sheds supported on structural steelwork of pleasing design and painted light green.

Both platforms have waiting rooms near or in direct connection with the approaches from the concourse, one on the station-side platform being constructed of brick, and two on the island platform, constructed of cast and wrought aluminum with glazed doors and side-wall sash. The different waiting rooms, all of which are heated and furnished with settees, vary in size, but the largest, which is on the intermediate platform, is 153 feet long by 13 feet wide.

Many signal changes.

The signal and interlocking changes made in connection with the improvements at Newark extend over approximately a mile, and include a new operating tower, a new 155-lever interlocking machine, and a large number of signals and switch machines. At present, of course, the signal and interlocking facilities are developed only to the extent of taking care of the new tracks put in service.

Fig. 8. — Position-light signals at the east end of the station improvements, looking west toward the new river bridge and the station. — All tracks are electrified.

The new interlocking tower, which is called « Dock » tower, is located immediately east of the Passaic river, approximately 1 500 feet east of the new passenger station. This tower, which also houses the new bridge control and power generating equipment, to be described in a subsequent

issue, is a three-story brick structure with a basement, the first floor and basement being 123 feet 8 in. long by 25 ft. wide, and the second and third floors being 71 ft. 4 in. long by 25 ft. wide. The basement houses principally electrical cubicles, busses, circuit breakers and other such equipment, and also provides space for air compressors and for small work shops for the track and signal forces. The ground-level floor is the power generating floor, essentially for bridge operation and station lighting; the second floor is occupied essentially by signal relays and associated equipment, while the third floor houses the interlocking machine and bridge control desk.

The interlocking machine is of the electro-pneumatic type, and, at present, has 36 working levers. Of these 17 govern 37 signals; 13 govern 21 switches; 3 govern smash boards; 1 is a check lever; 1 is a traffic lever; and 1 is called a bridge master lever. There are at present 99 spare levers on the frame and 20 spare spaces. A continuous, four-indication cab-signal system prevails throughout the territory, and all wayside signals are of the position-light type. In addition, approach locking and S. S. protection are provided. All switch machines are of the A-5 type, with C. P. valves, the air for operation being supplied by two 225-cu. foot compressors, with automatic electric drive, located in the basement of the tower.

Special features of the signal instal-

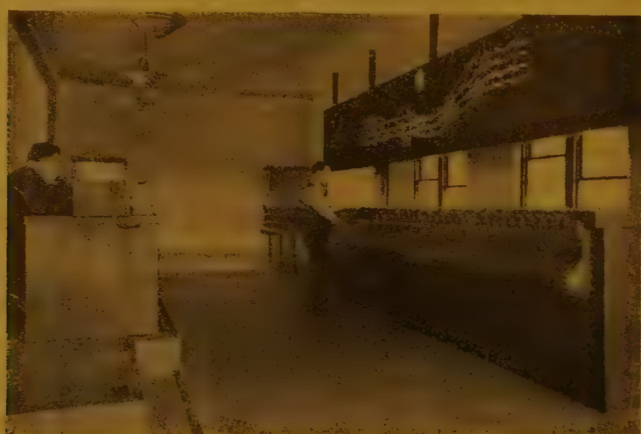


Fig. 9. — Within the new « Dock » interlocking tower, showing the new 155-lever electro-pneumatic interlocking machine, the illuminated model board, and the operator's desk.

lation include a model board, which incorporates not only the usual track and signal indications, but also indications of the electric trolley sectionalizing set-ups, and the fact that all wiring of the interlocking machine has fireproof insulation. Another interesting feature is the interlocked arrangement between the signal equipment and the bridge operating mechanism. In this, before the signals can be cleared, the movable span must be properly seated and locked, and all power to the bridge cut off. Similarly, before the span can be raised, the signals must be set at stop, the bridge smash boards

put down, the span and rail locks withdrawn, and the master lever of the interlocking machine put at normal. Furthermore, all track circuits must be unoccupied between the smash boards each way from the bridge. All of these conditions are indicated electrically, so that the signal operator has directly before him visual indication of the situation at all times.

The new interlocking replaces an old interlocking, called CK interlocking, which, with a 35-lever electropneumatic machine, is located immediately west of

Fig. 10. — New « Dock » interlocking and bridge control tower, showing the power transformer station in the foreground, and the new river bridge in the background.

the Passaic river, but which will be removed. In the old arrangement, all power and signal lines crossing the river were carried in either submarine cables or cables directly on the old draw bridge, with circuit breakers at the ends of the swing span. In the new arrangement, all circuits, including signal, traction and station lighting, are carried under the river in a tunnel of 6-foot inside diameter and 600 feet long, located approximately 50 feet north of the new river bridge. This tunnel, which is essentially a concrete pipe with a 12-inch wall, poured in place, was constructed under air pressure, employing steel liner plates for a shield. It has a cable chamber on each side, one for high tension lines and the other for low tension lines, and between them there

is a 2 1/2-foot passageway. At the ends, the tunnel is connected to the surface by concrete shafts, 10 feet square and approximately 50 feet deep, with splicing chambers directly above. Forced ventilation is provided to clear the tunnel of dead air when it is necessary for men to enter.

Other improvements.

In connection with the major improvements at Newark, numerous auxiliary improvements were necessary or found advisable, the more important of these including the construction of the new steam plant for heating the station; new express handling facilities to replace facilities which had to be removed to permit the new passenger station construction; and the provision of additional local freight handling facilities because of the necessity for removing certain freight handling facilities in the vicinity of the old station.

The new heating plant, which is located approximately 600 feet west of the station on the north side of the new station tracks, is a steel and brick structure approximately 50 feet square by 66 feet high, and has a radial brick chimney 175 feet high. It is equipped with two stoker-fired water-tube boilers of 300-H.P. capacity, which deliver steam to the station at high pressure in two six-inch seamless steel pipe lines. Condensation from the heating system is pumped back to the heating plant in a four-inch wrought iron return line. Both the supply and return lines are carried to the station in a pipe tunnel beneath the one island platform which has been constructed.

Coal is delivered to the plant over a ground-level track hopper on the north side, and from this is conveyed to the stoker hoppers by means of a 1/2-yard clamshell bucket, which is hung from an overhead gantry but which is operated from the firing floor level. Cinders are conveyed to a large storage bin above the roof by means of a steam jet vacuum system, and from the storage bin are drawn off periodically over a chute to a car spotted on the coal delivery track.

The express handling facilities of the Railway Express Agency, formerly located on the site of the new passenger station, have been moved to a point about 1 1/2 miles west of the station, on the north side of the main tracks, directly at the head of Broad street. The new facilities consist essentially of a one-story building 587 feet long by 66 feet wide, which includes a brick-enclosed office section at the east end, 144 feet long, and a shed section at the west end, 443 feet long. The shed section, which has a steel frame, is equipped on both sides with rolling steel doors, and above the doors it is enclosed with corrugated asbestos-protected metal siding and roofing.

The north side of the shed is served by a wide driveway, which extends beneath the shed roof a depth of 26 feet, affording back-up space under shelter for the longest trucks. The platform within the shed, which is at tailboard height, is approximately 35 feet wide. On the south side, this is extended out about 5 feet, under cover of the roof, to serve two express car tracks on this side. The new facilities provide space in the shed area for a battery charging generator room and a truck washing stand.

The additional local freight facilities are located directly south of the express building, on the south side of the main tracks, and form an extension of existing facilities at this point. The expansion provided here consisted mainly of extending 15 tracks, arranged for the most part in groups of two, approximately 500 feet to the east, and providing concrete driveways between the different extended groups as extensions to existing stone block driveways. In

addition, however, a new small yard office and an auto and stock unloading platform were provided. Future plans call for the further lengthening of the tracks and platforms a distance of 250 feet, when requirements demand.

The extensive improvements at Newark have been carried out under the direction of T. J. Skillman, chief engineer of the Pennsylvania, A. C. Watson, chief engineer of the New York zone, and L. P. Struble, engineer—Newark Improvements. The improvements, except for the station building, the superstructure of the river bridge, and the signaling and trackwork, were made under contract by J. Rich Steers, Inc., New York. The station building and platform enclosures were built by George A. Fuller Company, New York. The signal work has been installed under the direction of J. S. Gensheimer, engineer of telegraph and signals, New York zone; the electrical work in connection with the station was carried out under the direction of J. V. B. Duer, electrical engineer, Pennsylvania system; and the trackwork was done under the direction of R. R. Nace, chief engineer maintenance of way, New York zone. The architects for the station were McKim, Mead & White, New York.

[621. 135.2]

Locomotive axle failures and wheel-press fits [1],

by T. V. BUCKWALTER,
Vice-President, The Timken Roller Bearing Company,

and P. C. PATERSON,
Railway Department Development, The Timken Roller Bearing Company.

(Railway Mechanical Engineer.)

Although it has been appreciated for some time that railroad axles have been failing because of undue concentration of stress, little has been known about how to correct the situation. In the search for an improved economic axle life the Timken Roller Bearing Company early in 1933 inaugurated a research program to learn, if possible, how to avoid axle failures which had been occuring at stresses below the usual safe working range. Fatigue failures occuring just inside the face of press-fitted members will be discussed in this paper. The program carried out at the University of Michigan and the Timken physical laboratory included both physical tests and photo-elastic studies and during the research much valuable data were gathered.

Application of the usual formulas for determining the press-fit pressure between two cylinders gives a uniform pressure distribution when the cylinders are both of the same length. In the case of a sleeve or wheel pressed on an axle, however, the press-fit stresses are no longer uniform, but increase rapidly near the end faces of the sleeve due to the greater compressive resistance of the protruding portions of the axle. This unfavorable stress condition is further complicated by the fact that the axle rotates under bending stresses — tension on the top and compression on the bottom side.

The end faces of the sleeve have a tendency to impinge against the compression side of the axle. As the axle rotates the alternate contraction and

(1) Abstract of a paper presented before the Engineers Society of Western Pennsylvania, January 29, 1935.

elongation of the axle fibers produces a minute sliding action of these faces on the axle. This periodic action produces a band of abraded axle metal near the end faces of the sleeve which is very noticeable in the usual press-fit failures and is often accompanied by a brown rust formation which introduces a further weakening effect known as corrosion fatigue.

Physical tests.

Data pertaining to physical tests on carbon-steel axles are presented in figure 1.

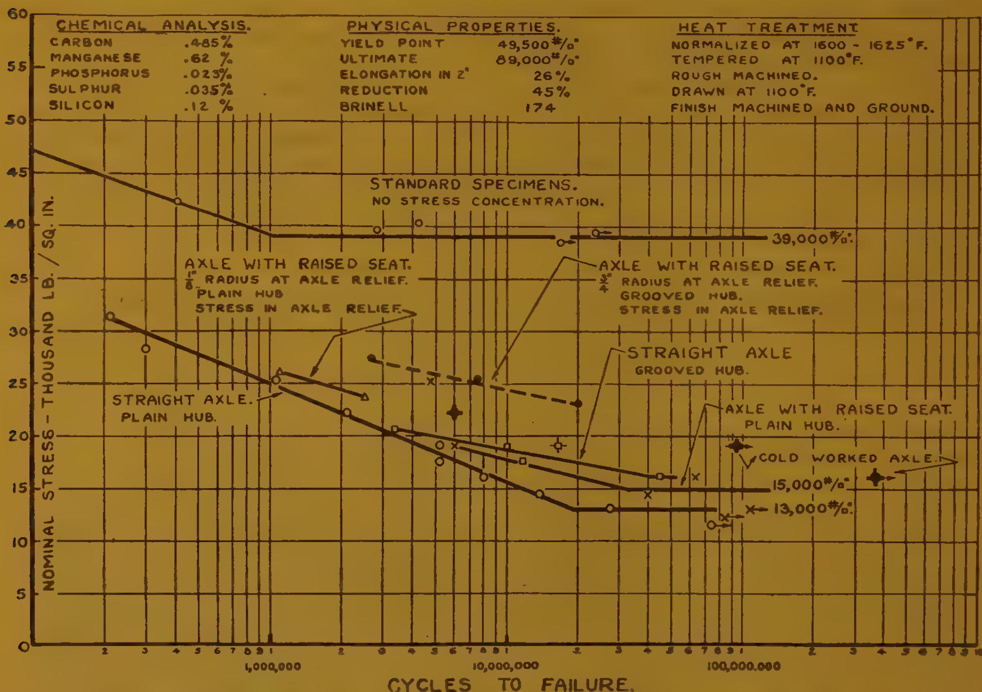


Fig. 1. — Fatigue test data of carbon-steel axles, normalized and tempered. Specimens 2 inches diameter; press- fit of hub, 0.001 inch tight.

Although the work is not yet complete, the data now available tend to favor : (*a*) raised seat on the axle; (*b*) stress relief groove in wheel hubs, and (*c*) cold working of wheel seats, as prolonging the life of axles. For example, some test specimens embodying these features have already shown 40 times the life of normal carbon-steel plain axles. It should be noted that the possibilities of improving axle life by means of cold working the wheel seats is recognized as an outstanding development, both in this country and abroad, and is already the subject of intensive research on the Timken program.

The data derived from tests on 64 axles indicate an improvement of 25 % in fatigue strength of plain carbon steel as used in locomotive axles without cold working. Thus an axle having a normal life of 400 000 miles under present-day conditions might be given a life of at least 1 500 000 miles by comparatively

minor modifications. However, if the axle is cold worked in addition to being provided with raised seats and stress-relief grooves in the wheel hubs, it is within the realm of possibility that practically the full fatigue strength of a normalized steel axle (39 000 lb. per sq. inch) can be made available for design purposes.

The use of alloy steels when properly heat treated offers opportunities for marked improvement in axle life, but unless the alloy steel is properly heat treated there is no advantage whatsoever over carbon steel.

The physical tests, made on 2-inch diameter shafts, were conducted on cantilever type rotating beam machines. Loads were applied to the specimens through double-row Timken bearings mounted in self-alining housings. The press-fitted members were applied to the specimens 0.0005 inch tight per inch of diameter. The machines were operated continuously at 2 000 r.p.m. until failure occurred.

Photo-elastic study of press-fitted members.

A qualitative analysis of a series of photo-elastic studies showing the stress concentration developed in various press-fitted assemblies, with particular reference to driving, trailer and tender axles, is herewith presented, discussing in detail

a) equipment

b) character of photo-elastic fringes on an axle not subject to press-fit stresses

c) character of photo-elastic stresses on integral shoulders and press-fit members

d) character of fringes at fillets on wheel hubs

e) photo-elastic fringes with press-fit members, such as driving or tender wheels, having stress-relief grooves on the inner face of the hub.

These photo-elastic studies show that the strength of an axle is considerably weakened by the conventional press fit. This checks with service and fatigue tests as to where axle failures occur. Means of improving this stress concentration are indicated by the tests of various shaped grooves on the inside face of the wheel hub and by the use of a raised wheel seat.

The following conclusions may be drawn from this photo-elastic study :

1. The conventional type of press-fit assembly of a plain wheel hub on a uniform diameter axle, figure 6, gives a stress concentration of about the same magnitude as a very small fillet; in this comparison the hub is considered as being machined as an integral part of the axle, as in figure 5.

2. The effect of a radius at the inside hub face of the wheel, figure 6, offers no noticeable improvement over a sharp corner on the wheel hub, figure 7.

3. A wheel hub mounted against a shoulder on an axle, figure 8, gives a weaker axle construction than the conventional assembly.

4. A grooved wheel hub mounted on a uniform diameter axle, figure 9, reduces the stress concentration considerably over the conventional assembly.

5. Of the six types of relief grooves tested type 5, figure 10 (also photo-elastic studies figures 9 and 12) gives the least stress concentration. The other types of grooves tested, which differed in shape, depth and location, also show improvements over the conventional assembly.

6. A plain type of wheel hub mounted on an axle with a raised wheel seat or pad, figure 11, gives an improvement in stress concentration over the conventional assembly.

7. A certain height of pad gives maximum reduction in stress concentration and the use of a higher pad does not give any further beneficial effect.

Design tested and equipment used.

The axles studied were of the conventional outboard type. The Bakelite test

models were designed to show stress concentration and distribution as affected by modifications of the inside face of the wheel hub and by changes in wheel-seat diameter.

All axles studied had a journal diameter of 8 1/2 inches, but the wheel-seat diameter varied from 9 3/4 to 12 inches. The wheel-hub sections at the inside hub face were approximately 4 inches thick. Various wheel-hub modifications were tested also. All models were made of Bakelite approximately 3/8 inch thick and were one-sixth of the actual dimensions of the wheel-hub and axle assembly.

Method of loading and photo-elastic set-up.

This is shown in figures 2 and 3. Figure 3 indicates the method of simulating the press-fit condition, calibrated springs pressing the hub against the axle. Figure 2 shows a general view of the complete axle and wheel model under load in position in the photo-elastic set-up. Long steel beams carrying pans are fixed to the ends of the axle model. This construction permits pure bending stresses to be applied to the model so that simultaneous bending and press-fit stresses may be obtained.

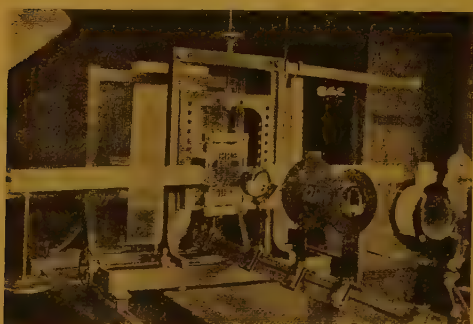


Fig. 2. — General view of photo-elastic equipment and model in position.

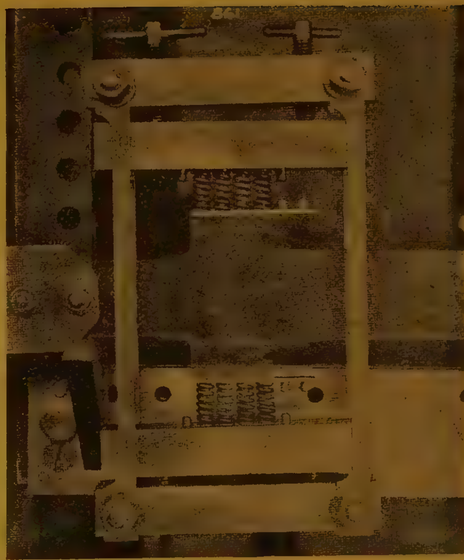


Fig. 3. — Close-up of wheel and axle model with calibrated springs to simulate press fit.

A photo-elastic study showing fringes for the case of a uniform beam with pure bending stresses only is shown in figure 4. Parallelism and equal spacing of fringes indicate uniform stress distribution. Fringe marked *0* is the neutral axis. Shearing stresses shown are di-

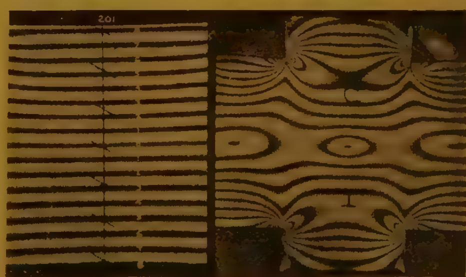


Fig. 4. — Fringes in uniform beam under bending stresses.

Fig. 5. — Fringes in beam with enlarged portion representing wheel hub when under bending stresses.

rectly proportional to fringe order marked on each fringe.

Another study of bending stresses is shown in figure 5. This covers the portion of an axle enlarged to represent a wheel hub which, in this case, is studied as an integral part of the axle. Note the crowded and sharply curving fringes at the very small fillets adjoining the enlarged portion, which indicates localized stress and the point where failure will occur. This integral study shows that the conventional press fit gives a

Fig. 6. — Straight axle seat with hub assembly having a 1/8-inch radius on the inner face. Stress concentration near the inner hub face corresponds with the zone of failure in service.

stress concentration of about the same magnitude as a very small fillet or sharp corner. Compare this with figure 6.

Discussion.

A conventional press fit of a plain wheel hub on a uniform diameter axle, figure 6, gives peak press-fit stresses at section from the axle into the hub. It should be noted that the maximum bending stresses also occur at the same position on the axle. The bending stresses are much greater than those normally calculated due to the abrupt change in section from the axle into the hub. It is evident, therefore, that both these unfavorable conditions occur at the same location on the axle, thereby creating an accumulative weakening effect. If in the case where a wheel hub is mounted against a shoulder on an axle, figure

Fig. 7. — Straight axle and hub with sharp corner.

Fig. 8. — Axle with hub mounted against a shoulder.

8, the hub radius is made to fit the small shoulder radius; then, in addition to the weakening effect mentioned above there exists the unfavorable effect of the stress concentration of the fillet occurring at this same critical section. This type of shoulder construction weakens the axle, but its effect is sometimes small as compared to the total stress concentration present.

A conventional press fit of a plain wheel hub on an axle with raised wheel seat or pad, figure 11, has three beneficial effects : A more gradual change in section takes place between the axle and the wheel hub; the peak pressure at the end face of the wheel hub is reduced, due to the decrease in lateral restraint of the protruding axle, and the bending stresses in the axle near the end of the pad are reduced at the point where the press-fit stresses are a maximum.

A grooved wheel hub on a uniform diameter axle, figure 9, presents a very favorable fringe pattern, showing an improvement over the cases discussed above. Grooving has the effect of relieving the peak press-fit stresses near the end face of the hub. This is due to the flexibility of the lip on the hub which prevents the building up of high stresses at this point. Grooving also effects a gradual transition in section from the axle into the sleeve, functioning in the manner of a large fillet.

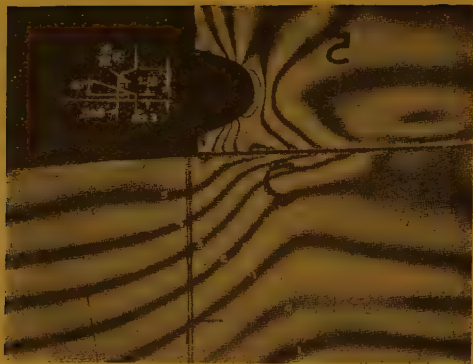


Fig. 9. — Straight axle with grooved wheel hub assembly, type 5. — Note the reduction in axle stress concentration.

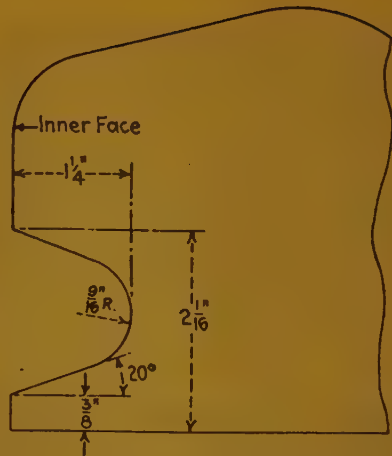


Fig. 10. — Wheel hub relief groove No. 5 which showed best improvement in reduced axle stresses.

From the standpoint of economical design, grooving appears to offer improvement over the use of a plain hub mounted on a pad on the axle. The axle forging design is simplified and space requirements are reduced.

The combination of a raised wheel seat or pad with a grooved wheel hub, figure 12, gives a very favorable fringe pattern. This combination may be expected to show some improvement over all other designs. Preliminary analysis of the Timken photo-elastic studies, however, does not show definitely how much improvement is represented by this combination over the case where a grooved hub is applied on a straight axle, figure 9. This question is being given further analysis.

Six different types of grooves were tested. It is natural to expect that the larger the groove and the thinner the wedge-shaped lip the greater will be the improvement in stress concentration. There are certain limits to groove formation, such as reduction in wheel tonnage, reboring of wheel centers, and the danger of failure of material with thin sections at the lip. Too thin a lip is also undesirable because of its inability to transmit sufficient pressure to give the desired reduction in peak press-fit pressure.

The best groove formation was found to be type 5, figures 9, 10 and 12, and it is expected that further studies now under way will indicate that the pressure peaks will be reduced for this type over the other grooves. This groove shape has a 20-degree angle tangent to the groove radius and gave better results than either the 30-degree angle or the 45-degree angle or any of the other groove formations.

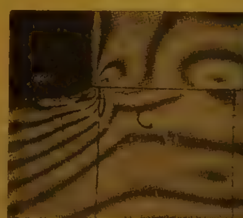


Fig. 11. — Raised seat on the axle with a hub having a sharp corner.

Fig. 12. — Raised seat on the axle with a hub having relief groove. — Note the difference in concentrated axle stresses.

Summary of stresses — 7 5/8 inch axle.								
Line No.		Section at outside face of hub « A-A ».	Section at center line of rail « B-B ».	Section at center line of hub « C-C ».	Section at inside face of hub without relief « D-D ».	Section at inside face of hub with relief « D-D ».	Section at point 21″ from center line of axle « E-E ».	Section at center line of axle « F-F ».
1	Bending from rail reaction	4 700	13 800	13 400	11 500	11 500	15 000	15 700
2	Direct compression from thrust reaction . . .	...	...	-500	-500	-500	-500	-700
3	Net bending stress . .	4 700	13 800	12 900	11 000	11 000	14 500	15 000
4	Radial hoop stress . .	12 300	12 300	14 800	12 300	4 000	...	...
5	Tangential hoop stress . .	12 300	12 300	14 800	12 300	4 000	...	...
6	Crushing stress . . .	3 400	2 400	...	3 400	3 400	...	...
7	Direct shear from rail reaction	-700	...	...	-700	-700	...	...
8	Maximum shear . . .	13 700	13 500	14 800	13 700	5 400	...	...
9	Maximum combined tension	16 300	22 100	22 900	20 300	14 300	14 500	15 000

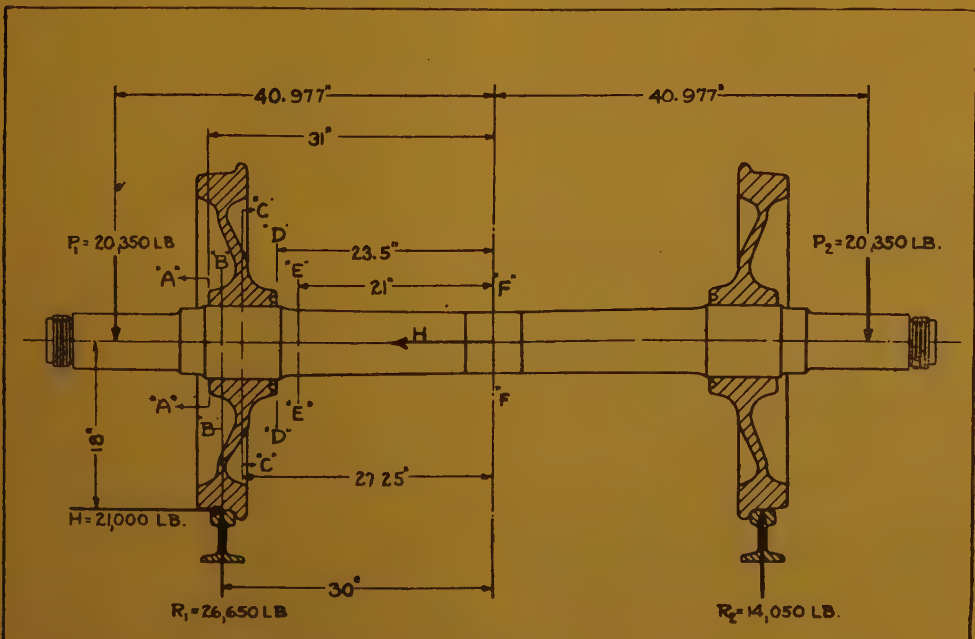


Fig. 13. — Axle-stress calculations for outboard-bearing axle under the loading shown.

Various heights of wheel-seat pads were investigated. It is apparent that some particular height of pad gives maximum reduction in stress concentration and that the use of a higher pad does not give any further appreciable beneficial effect. This phase is being given further study.

A two-dimensional stress distribution is indicated in these photo-elastic studies and the question may arise as to the applicability of this method in view of the three-dimensional case actually present in the press-fit assembly. However, these photo-elastic studies have their value from a qualitative standpoint. They permit a comparison of one fringe pattern with another; determine the stress concentration due to shape; give an indication of the distribution of pressure across the length of the press fit; and develop a broader aspect of the entire problem. With this in mind fatigue tests can be planned more directly toward a definite design, thereby eliminating the necessity for determining certain variables from a series of fatigue tests requiring considerable time and expense. It is not believed that definite numerical data can be obtained on stress concentration from photo-elastic studies. It is necessary to resort to fatigue tests in order to determine the actual stress concentration as developed by the combination of the effects of size, sensitivity of materials, three-dimensional stress system, and corrosion fatigue.

Further work using a sensitive lateral extensometer is being continued by the Timken Roller Bearing Company at the University of Michigan to determine the principal stresses.

Stress calculations.

Figure 13 and accompanying table presents a tabular analysis of stresses occurring in a typical outboard-bearing railroad axle. It is particularly interesting to note that the maximum shear stress at the inside hub face using a stress relief groove in the hub is only 5 400 lb. per sq. inch as compared with a stress of 13 700 lb. per sq. inch when a plain type hub is used.

A comparison of the Timken type axle, which embodies the features discussed in this paper, with the standard A.R.A. type E axle, is shown in figure 14. The Timken axle is shown above the center line, while the A.R.A. axle is indicated below.

The A. R. A. axle has three concentrating factors consisting of : (*a*) the presence of a shoulder on the portion of the axle subjected to high bending stress; (*b*) use of a comparatively thick hub without relief, building up higher stress concentration at the face of the hub, and (*c*) the superimposing of (*a*) and (*b*), producing maximum stress concentration at the inner hub face (illustrated in worst possible form in figure 8).

Railroad axles for outboard-bearing engine trucks, drivers, outboard trailers, tenders, and freight and passenger cars are subject to improvement by using the Timken construction shown above the center line in figure 14 which eliminates the integral collar, introduces a stress relief groove, and provides a raised seat for the press fit of the wheel hub. There is also definite probability of improve-

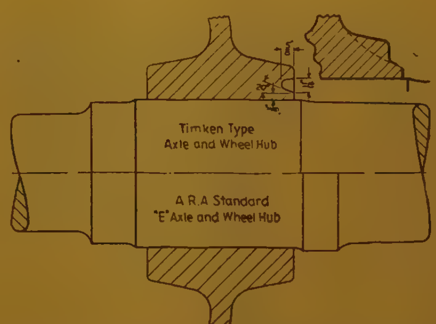


Fig. 14. — Timken improved type axle (*above*) compared with A. R. A. standard axle (*below*).

ment in axle service by cold working of the wheel seat.

Improvement in axle service could be obtained at slight expense in rolled wheels by providing an extended hub of reduced diameter corresponding with the 20-degree lip on the relief groove, as shown in figure 14.

The relief groove on the outer wheel hub face is not considered necessary because the stress in the axle is greatly reduced at that point, that portion of the axle not being subject to stress increase arising from flange action.

Physical tests for determining fatigue limit of reduced axle specimens are being continued at the Timken physical laboratory and at the University of Michigan. Photo-elastic studies are also being continued.

[621.135.2 & 625 214)]

High-pressure lubrication for journal bearings,

by G. WELTER.

(*Engineering*.)

The journal bearing is an important item in machines of very many kinds, and modern developments in machine construction generally and, particularly in this connection, the development of high-speed rail transport, demand that greater attention shall be paid to it than has been usual in the past. If the journal bearing is to compete successfully with ball and roller bearings, the use of which is gradually extending, it must be improved both from the technical and commercial points of view. The main disabilities of the ordinary plain bearing lie in the friction losses which are associated with its use, particularly during starting-up and in the early stages of running, and the wear and tear and loss of power which accompany this friction. In any attempts to improve the bearing, it is also desirable to consider the possibility of improving its reliability and load-carrying capacity. The consideration that the friction moment of the journal bearing is abnormally large, particularly at starting, leads naturally to the conclusion that the conditions might be improved by an alteration in the lubricating arrangements. The relation between the bearing and the lubricant is so close, however, that, in any satisfactory solution of the lubrication question, the nature of the bearing metal must form an important factor.

The proposals made by the author, and described in this article, aim at the elimination of the disadvantages of the present normal type of journal bearing. His system consists in the employment, in addition to the normal lubrication, of special high-pressure lubrication which is used in the zone of greatest pressure at the top of the bearing. The extra lubricant is supplied at a pressure of 100 atmospheres to 200 atmospheres (1 500 lb. to 3 000 lb. per square inch) so that the bearing, with the load it carries, is lifted free from the shaft, an oil cushion being formed between them so that all metallic contact is eliminated. With this arrangement, the friction moment approaches a zero value, and when starting up is less than the friction moment at normal running speed with an ordinary bearing. The system was investigated on a large bearing-testing machine employing a shaft 120 mm. (4.7

in.) in diameter. The extra lubrication was supplied by a Bosch high-pressure lubricator of the type which is largely employed on compressors working up to several hundred atmospheres and for locomotive work. The friction between the bearing and the shaft was measured by means of a friction balance connected to a dynamometer. A load of six tons was imposed on the bearing, and tests were carried out, both at starting-up and when running, at low temperatures of 3° to 5° C. (37° to 41° F.), as well as at the air temperature of 20° C. (68° F.). Comparison tests were also made with well-known make of roller bearing at 20° C.

Characteristic results are plotted in figures 1 to 5. The curves connecting the dynamometer reading with time which are given in figs. 1 to 3, refer to a railway-carriage bearing brought from rest up to a speed of 250 r.p.m. in a few seconds. This corresponds to a rate of travel of the vehicle of 45 km. (28 miles) an hour. Figure 1 shows the friction values plotted to a very open scale for the first 60 seconds, and figure 2 gives curves for 10 minutes.

Curves for the same bearing, with and without high-pressure lubrication, are given in each case, and clearly show the much lower readings obtained when it was in operation. As is well known, the starting resistance of a normal journal bearing is very high, and in this case the initial dynamometer reading was about 150 to 170 kgr., falling to 17-19 kgr. in 10 seconds, and reaching 14 kgr. after 50 seconds. As a result of insufficient oil supply in the area of greatest pressure, it then rose to 20 kgr. (fig. 1). In the first part of the curve the observed maximum and minimum readings are plotted and a fair curve drawn between them. The contrast between this curve and the curve for the high-pressure lubricated bearing plotted below it is marked. In this case the curve rises from a point in the neighbourhood of zero to a maximum value of 5.5 kgr. It then asymptotically approaches a minimum value of about 2.3 to 2.6 kgr. The curve is quite steady, and there was no oscillation of the indicating arm of the dynamometer.

In the case of the longer series of observations, extending over ten minutes, which are plotted in figure 2, the hatched area A under the curve for the normal bearing is a measure of the power loss due to friction during the first ten minutes' running, and if this is compared with the hatched area B under the curve for the bearing with high-pressure lubrication, it will be seen that the loss in the first case is about three times that in the second. This figure also contains a curve for the grease-lubricated roller bearing, which, it will be seen, lies somewhat higher than that for the high-pressure lubricated bearing. The results plotted in figures 1 and 2 were obtained with the bearing at room temperature of 20° C. The actual rise in temperature of the bearing during this period is plotted in figure 3. It will be seen that while the normal bearing rose in temperature by 27° to 28° C. in ten minutes, the high-pressure bearing temperature increased only some 10° to 11° C. in the same period.

Still more striking differences between the two bearings were shown in the tests carried out at low temperatures, which are plotted in figures 4 and 5. In these tests the speed of the shaft was rapidly brought up to 150 r.p.m., and at the end of two minutes again rapidly advanced to 250 r.p.m., being further stepped up to 350 r.p.m. after two further minutes.

The unsteadiness of the friction curve of the plain bearing is very marked, the swing of the indicating arm in the first two minutes being as much as 10 kgr. The maximum and minimum readings

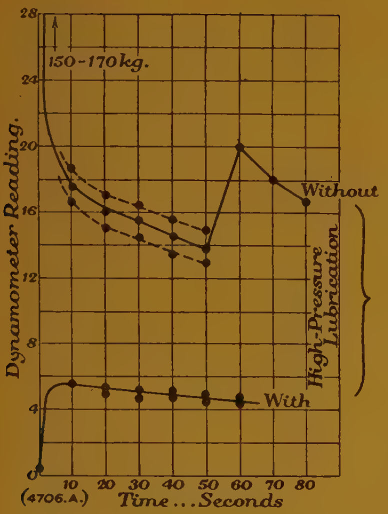


Fig. 1.

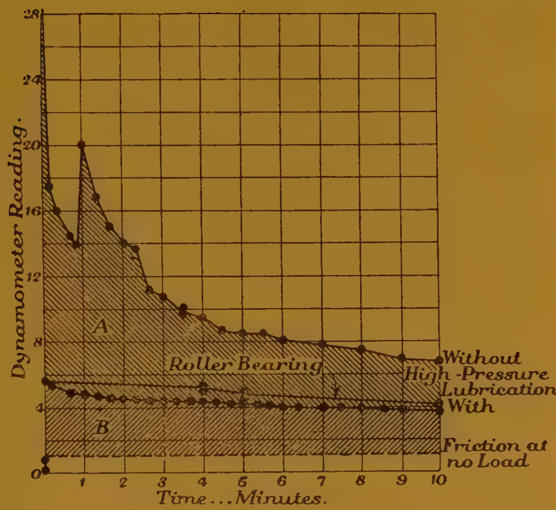


Fig. 2.

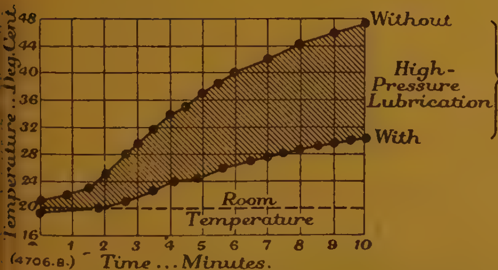
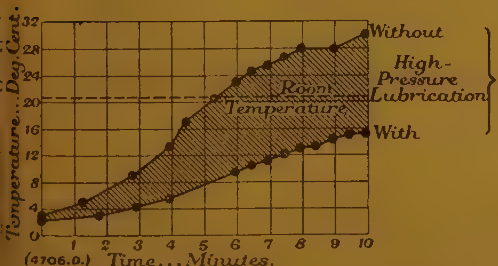
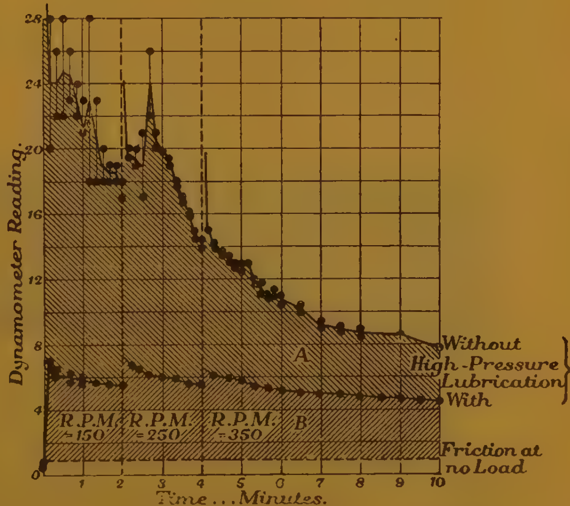


Fig. 3.



(Engineering.)

Fig. 5.



(Engineering.)

Fig. 4.

are plotted for this part of the curve. The ratio of the power losses for the two curves, as indicated by the hatched areas A and B, amounts to from 1 to 3 to 1 to 4 in the early part of the running period and from 1 to 2 to 1 to 3 later. These observations were made at a room temperature of 20° C., but with the bearing at an initial temperature of about 3° C. The rise in temperature of the bearing with the two types of lubrication is shown in figure 5. The difference in temperature of the bearing under the two conditions amounted to some 14° to 15° C.

The investigation illustrates clearly the way in which the performance of the ordinary plain bearing may be improved by the use of high-pressure lubrication. At the moment of starting, the ratio of the friction values of a high-pressure bearing and a normal pad-lubricated bearing stands at the remarkable figure of about 1 to 300, while at the end of ten minutes it has fallen to about 1 to 3. This implies that about two-thirds of the work normally absorbed in friction can be saved. If these figures are considered in relation to, say, a large railway on which the total number of times which vehicles are started and stopped may amount to very many thousands a day, it will be realised that the potentialities for power saving are very great. Careful and extended tests carried out by the Swedish Ball Bearing Company show that the fuel saving in railway operation as a result of fitting roller bearings to rolling stock average 11 to 12 %, while Messrs. Fichtel und Sachs A. G., as a result of similar tests on railway vehicles and tramcars, claim a figure of from 10 to 15 %. As the pressure-lubricated bearing can show similar savings at lower capital cost, it should be of great value not only in railway vehicles, but in machinery of all kinds.

[621. 135.4, 625. 14 (.01 & 625. 215]

Fast running without derailment,

by Dr.-Ing. BÄSELER, of the Deutsche Reichsbahn Gesellschaft.

(*Diesel Railway Traction*, supplement to the *Railway Gazette*.)

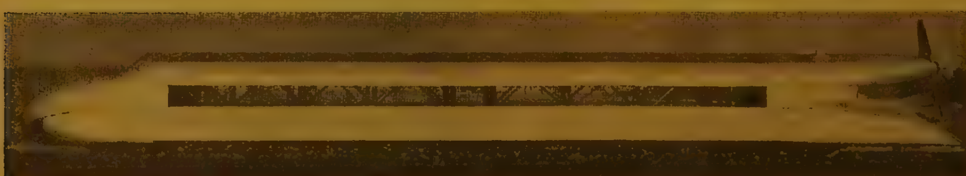


Fig. 1. — The Kruckenberg railcar as it was when it attained the record speed of 143 m.p.h.

Present-day conditions, coupled with the constant rivalry of road traction, make it imperative to face the question of increasing the speed of railway travel. Whilst no finality is claimed for the ensuing remarks, they may help to crystallise the fundamental problems involved. It seems probable that in Germany, at least, high-speed rail vehicles of the future will fall into two groups : (1) ex-

press railcars, with streamlining a primary, and weight a secondary, consideration, and (2) fast railcars, intended for working fairly heavily graded lines, and therefore as light as possible and capable of very quick speed recovery. The express car would have to be able to run its engines at full capacity for hours on end. This comes easily to a good steam or electric locomotive but, generally speaking, a diesel engine is not so well suited to the task.

The *Flying Hamburger* is composed of two long cars and has an engine power of 820-B.H.P. (although 1 200-B.H.P. is to be used for future cars). For a corridor train comprising ten cars and having an equal service capacity, five times as much horsepower would be needed, say 4 000 to 6 000. True, the end resistance falls, but the side resistance remains the same unless wind sheathing is employed, which is not easy to fit should the train not always form a set. There seems little sense in providing so much power, but having it all grouped in one unit is useful, as its working can be much better supervised. Fewer defects and failures are thus experienced, but in any case the failure of a part in a multiple-unit system is less grave than that of a steam locomotive.

The question of speed on curves is a vital one in this problem of attaining higher travelling rates. When one considers that 20 % of the main lines of the Reichsbahn are on curves, and that in central and south Germany the percentage is considerably higher, it is apparent that no great increase in speed is to be hoped for until some radical change in German practice is made. On such sections a fast car has the advantage over an express car, on account of its great accelerative powers. The fact that the automobile has not yet been equalled in this respect is all the more reason why an attempt should be made, and the use of a fixed track offers a chance to do so.

The question of curves.

Curve, speed and superelevation stand in a fixed relation, depending on the law of centrifugal force,viz., $\left(g\,\frac{V^2}{R}\right)$ or, otherwise expressed, V (km.p.h.) $= K\sqrt{R}$. The constant K lies between 3 and 4 but nearer 4, according to contemporary railway practice. Taking the higher limit as a basis, it may be said that it is now usual to go to $V = 4\sqrt{R}$, thus :

R	*V*	*R*	*V*
m.	*km.p.h.*	*m.*	*km.p.h.*
900	120	500	90
750	110	400	80
625	100	300	70

Through the fixed relationship $\frac{V^2}{R} = 16$, or $\frac{V^2}{R} = \frac{16}{3.6} \times 2 = 1.23$, the value of the centripetal acceleration p is equally highly fixed for all curves at 1.23 m./per sec. per sec. Taken in conjunction with the mass of the vehicle or passengers, it gives the force with which the vehicle has deviated from the direct path. The German terms « track pressure » and « track acceleration » may be used, but it must be remembered that the latter, although similar in nature to starting acceleration, operates transversely to the direction of travel.

Superelevation is used to counteract centrifugal force. Its height is limited by practical considerations. In Germany, for instance, it is 110 and 120 mm.; in Austria 140 mm.; while on the severe curves of Switzerland 150 mm. is found. Now a track acceleration of 1.23 m. per sec. per sec. is $\frac{1.23}{9.81}$ = one eighth of the acceleration due to gravity. The superelevation must therefore be 0.125 of 1 500 mm. (track width) = 187.5 mm. Actually it is less, so that part of the

centrifugal acceleration ($p_{\ddot{u}}^{\pi}$) is not counteracted.

Superelevation	*pü*
120 mm. . . .	0.44 m.p.sec.p.sec.
140 » . . .	0.31 »
150 » . . .	0.25 »

In some cases it is higher, but not under German conditions.

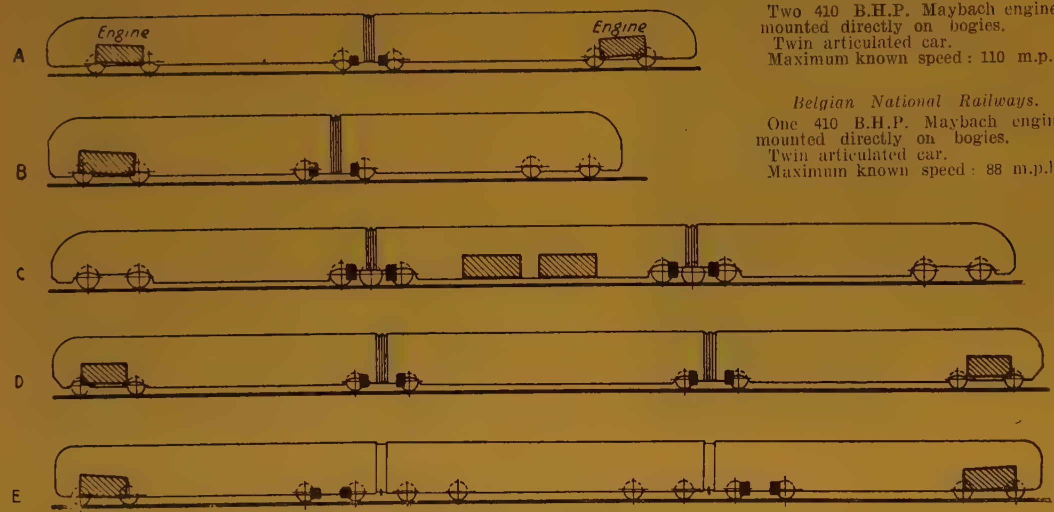
To increase speed on curves the first thought is to increase superelevation, which cannot as a rule be done, for slow trains also run on these curves. More difficulties arise on S bends, and engineers would like to flatten the line instead. Taking the highest value of 150 mm., or an inclination of 1 in 10, a tenth part of the centrifugal acceleration is counterbalanced. Suppose it is wished to raise the speed 50 %, which may also be expressed as from $V = 4\sqrt{R}$ to $V = 6\sqrt{R}$. The track acceleration rises when $V = 6\sqrt{R}$ to $p = 2.80$ m. per sec. per sec. Of this, $p_{\ddot{u}} = 2.80 - 1.00 = 1.80$ m. per sec. per sec. is not compensated and must be resisted by the vehicle and its passengers. Well designed cars conform to this rule with ease.

From the point of view of safety, the possibility of toppling over, or the dangerous removal of load from the inner wheels must be considered. The latter danger is very real in the case of steam locomotives having high boilers, and calculations show that such units would be inadmissible for the speeds contemplated, for the outer wheels would carry three-quarters, and the inner wheels only one quarter of the weight, which is not safe. As the gauge cannot be widened, future vehicles must have a low centre of gravity.

Security against derailment must also be considered. The Reichsbahn holds the opinion that the leading wheel is a danger point, a view that is countered by the remark that, were this so, there would be many more derailments. But trials and experiments show that the heavy pressure is there, and a bogie of 3.60 m. wheelbase feels it on curves of 800 m. radius. It is difficult to measure the exact forces at work, but a wheel that is running with a low margin of safety will derail should some untoward incident occur. There are some classes of locomotives with a reputation for derailing in a given set of circumstances. The danger occurs when flange pressure equals wheel pressure, but as a rule the safety factor is $n = 2$.

Taking the track acceleration previously mentioned, it is found that the flange pressure becomes 0.86 of the wheel pressure, and the safety factor drops to 1.16 when uncompensated. This is overlooking the fact that cars with a low centre of gravity, such as are proposed, will be helped by having the centrifugal force loading the outer wheel. As the centre of gravity cannot be lower than 1.00 m. above rail level, 12 % more load will be given on the outer wheels. The safety factor will be 1.30, which is not enough. It must also be remembered that in fast running, all dynamic forces show a marked increase, coupled with a greatly reduced time to recover from any small irregularity.

There is the permanent way itself to be considered also. Express traffic makes heavy demands on the track, and irregularities become intolerable at very high speeds. Fortunately all aspects of track maintenance have been greatly improved, including methods of detecting flaws. The damaging powers of some types of vehicle need to be studied and lateral stiffness of the permanent way must be ensured. It has been suggested that high-speed trains could be rendered safer by the use of check rails each side, such as the Marienfelde-Zossen line had before the war, when 210 km.p.h. (130 m.p.h.) was attained. It is, however, debatable whether this plan gives greater safety. Should a bad derailment occur in these new express services — no matter for what cause — the whole



Flying Hamburger.
Two 410 B.H.P. Maybach engines mounted directly on bogies.
Twin articulated car.
Maximum known speed : 110 m.p.h.

Belgian National Railways.
One 410 B.H.P. Maybach engine mounted directly on bogies.
Twin articulated car.
Maximum known speed : 88 m.p.h.

Dutch Cars.
Two 410 B.H.P. Maybach engines mounted on underframe of centre vehicle.
Triple articulated train.
Maximum known speed : 90 m.p.h.

Danish Cars.
Two 550 B.H.P. Frichs engines mounted on underframe at ends of train.
Triple articulated train.

Nord (France).
Two 410 B.H.P. Maybach engines mouned directly on bogies.
Three - car close - coupled train.
Not articulated.
Maximum known speed : 98 m.p.h.

Fig. 2. — Five types of streamlined trains on the Continent.

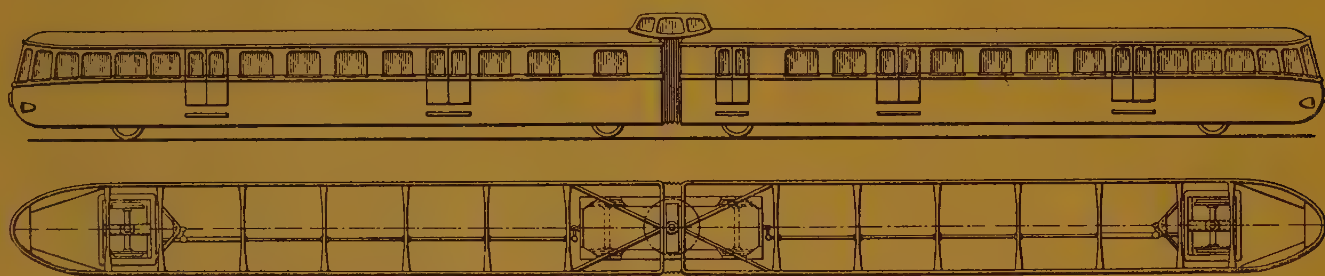


Fig. 3. — Waggonfabrik Uerdingen design for a high-speed four-axled articulated unit.

question would become one of utmost urgency.

The question of steering.

The danger, then, is in the action of the leading wheels when taking curves. Why, one might ask, does a motor car, which has a very great centrifugal effect, work with greater safety ? The answer is that car wheels are steered. If possible, the wheels of rail vehicles must be steerable, so that the leading flange need no longer do all the work and overcome the friction of the loaded wheels as it turns. The task of steering or directing the wheels has been given much consideration, and was actually adopted in the Kruckenberg car, as originally built, and high-speed travel demands it. A steering wheel is unnecessary because a long railway vehicle has at least three axles, and their relative positions on the curve can be made to give some steering action.

When $p_{ü} = 1.80$ m. per sec. per sec. and the axle is set radially, its own 25 % frictional grip will take up the 18 % side pressure without allowing the flange to gain the outer rail. The wheel now need only take up the uncompensated centrifugal effect, and the factor of safety rises to 2.8, or even to 3.0.

Evidently a car which could take curves fast and safely would alter high-speed services radically. It would also cut down costs, as less braking and subsequent acceleration would be necessary. One plan for such a vehicle would be a double car, seating from 100 to 130 persons. The axle number could be reduced from eight to six if an articulated bogie was fitted in the middle. Three axles, however, would suffice to carry the weight, or four, counting the middle bogie, and from 10 to 15 % greater acceleration should be obtainable than at present owing to net weight reduction. The Waggonfabrik Uerdingen has designed such a double car, having linked-up bogies and radial axles. Needless to say, strong, perfectly sprung construction is essential. Welded track completes this picture of perfection, but is still in the clouds of unreality.

Fig. 4. — End view of the streamlined articulated 500-B.H.P. Renault diesel train on the French State Railways.

Opposition to the proposal of steering axles is found in the objection that the effect comes too late. This is not so, particularly in the case of transition curves, and it is only at the beginning and end that some loss of benefit occurs, and even then a good factor of safety remains. There must always remain some points where speed must be reduced, but this can be assured by the use of a good automatic train control system.

Such a car as has been suggested would need to be made low, giving easy ingress for passengers, and the driver would be given a central cab. The curves must also be taken without causing discomfort to the passengers. Uncomfortable travelling is caused by slackness between wheel and rail, and a better fit

in this respect should be considered. It may be that a new design of seat will have to be evolved, comprising side sprung arm and head rests and other modifications giving extra comfort. Forewarned is forearmed, and a warning buzzer of dulcet tones might be employed to enable passengers to prepare themselves, mentally and physically, for a rapid deviation from the straight.

[621. 43 (.43) & 621. 8 (.43)]

The Trilok hydraulic transmission.

(From *Diesel Railway Traction*, supplement to *The Railway Gazette*.)

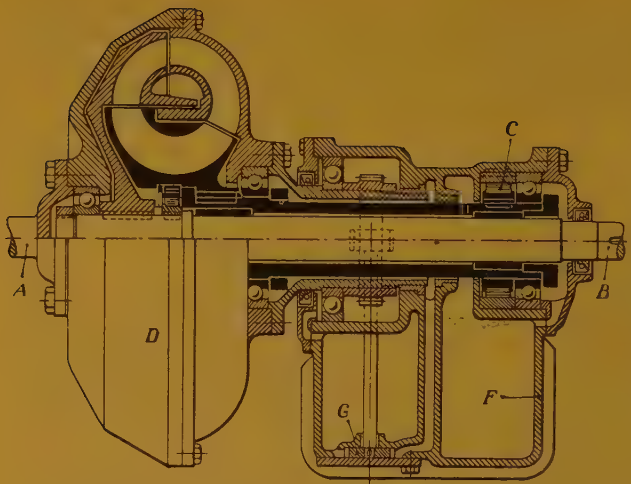
The Trilok hydraulic transmission, made by Klein, Schanzlin & Becker A.G., of Frankenthal, Germany, is based on the principles of the Föttinger hydro-kinetic drive and the Vulcan hydraulic coupling, but is simplified in construction by the combination of the torque-converter and the fluid coupling in a single hydraulic circuit. The essential features of a Föttinger transformer are the driving or pump blades, the driven or turbine blades, and a stationary guide-vane reaction member which takes up the difference of torque between the pump and turbine wheels. The hydro-kinetic coupling has no guide blades and is capable only of transmitting torque which is the same for the driving and driven, or primary and secondary, wheels of the coupling.

A torque converter attains its maximum efficiency at a given transmission ratio, determined by the design, whereas the maximum efficiency of a fluid coupling is reached when the driven shaft runs at the same speed as the driving shaft, and the slip is zero. The charecteristics of the torque converter and fluid coupling are thus complementary to each other, the converter providing increased torque at reduced speed of the driven shaft, and the coupling transmitting the driving torque at nearly the speed of the driving shaft. In order to combine these two functions in a single apparatus, it is necessary to arrange that the part used as a stationary guide vane or reaction member in the torque converter can operate as an additional turbine runner when the apparatus works as a fluid coupling.

Properties of Trilok transmission.

In the Trilok transmission two freewheel devices are used respectively to couple the dual-purpose member to the stationary casing when it is to act as reaction member (torque-converter), and to the driving shaft when it is to act as turbine runner (fluid coupling). The change from one condition to the other is effected automatically and at exactly the correct moment. Referring to figure 1, the pump impeller *P* is attached to the driving shaft *A*; the turbine runner *T* is keyed to the driven shaft *B*; and the dual-purpose wheel *S*, completing the hydraulic circuit *PTS*, is carried by a hollow shaft with freewheel devices at *C* and *D*. The rotating parts are carried by a stationary casing *F*, which also serves as container for the hydraulic medium. A small gear-pump *G* keeps the circuit *PTS* filled with oil under slight pressure, and also lubricates the bearings and freewheel mechanism.

When the resisting torque on shaft *B* is greater than the torque applied by shaft *A*, the guide vane member *S* tends to rotate backwards, but this is prevented by the mechanism *C* locking the



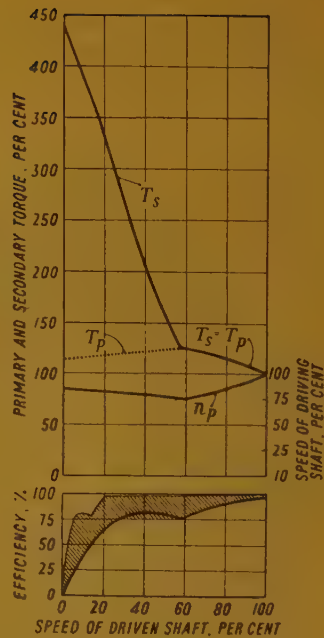


Fig. 1 (above). — Longitudinal section through Trilok combined torque-converter and fluid coupling.

Fig. 2 (right). — Operating characteristics of Trilok hydraulic transmission used in conjunction with a diesel engine.

hollow shaft of *S* with the fixed casing *F*. The part *S* is thus held stationary and acts as a reaction member, the transmission now being on the torque converter principle. As the torque required by *B* decreases, the speed of this shaft rises; and directly the required driving torque becomes less than the applied torque, the torque reaction on *S* reverses and this part begins to run forward in the same direction as *B*. The design is such that the speed of *S* rises rapidly, but it is prevented from overtaking *B* by the action of the mechanism *D*, which locks *S* to *B* and causes it to act as an extension of the turbine runner *T*. The transmission now operates as a fluid coupling without conversion of torque. Whenever the load-torque exceeds the driving torque, *S* falls behind *B*, comes to rest, tends to run backwards, and is again held by *C*, thus restoring the torque converter action.

The technical innovation in the transmission is the member *S* with its two locking devices, which enable the transmission to operate as a torque converter or a fluid coupling, according to the requirements of the load.

The torque characteristics of the Trilok transmission in conjunction with an internal combustion engine are shown in figure 2. The primary and secondary torques, T_p, T_s, as percentages of the torque at rated speed, are plotted against the speed of the driven shaft expressed as a percentage of its rated (direct-drive) value. The primary speed n_p, and the efficiency of the transmission are also plotted on the same base.

The efficiency varies with the load and speed, the range of variation being indicated by the shaded area in figure 2. The heavy curve represents the full-load efficiency. The efficiency is higher at

fractional loads and then often exceeds 98 per cent. The starting torque is 4.4 times the rated direct-drive value in the case represented by figure 2, and considerably higher starting torque can be obtained if required.

Fig. 3. — Outside view of a 250-B.H.P. Trilok transmission designed for use in a diesel railcar.

In common with other hydraulic machines, the Trilok transmission obeys the hydraulic laws of similarity. A change in the driving speed produces a proportionate change in the secondary speed; and the torques vary with the square of the speeds. At low speeds, *e.g.*, the idling speed of an internal combustion engine, the torque transmission is practically zero; the transmission then acts as a disengaged coupling and it is impossible to stall the engine. Similarly, the engine can be started light, even though the output side of the transmission be held stationary. Any desired vehicle speed from zero to maximum is obtained simply by moving the engine throttle, the hydraulic transmission adapting itself automatically to every change in tractive resistance and load. No operating rods or other control connections are needed on the transmission, and there is no interruption of torque transmission or tractive effort. The addition of a simple device permits the engine to be used as a brake.

[**625. 162** (.73) & **656. 259** (.73)]

Street crossing protection on the Northern Pacific.

(Railway Signaling.)

In several cities on the West Coast, such as Seattle, Wash., and Tacoma, the Northern Pacific has installed highway crossing signals. The purpose of this article is to explain the types of signals used, the methods of control and the results obtained in better protection at each of several typical installations in this territory.

In Seattle, Spokane street, an east and west thoroughfare with two separate lanes of pavement each 30 feet wide, is crossed by three parallel lines of the Northern Pacific, running north and south. The crossing of Spokane street at Second avenue involves a double-track line leading to the passenger station and a single-track line branching off to West Seattle. At Colorado street, two blocks west, the crossing of Spokane street involves three tracks leading to the freight yards. At East Marginal Way, one block further west, the crossing includes one joint track, used for switching.

The street traffic on Spokane street involves about 36 000 vehicles daily. The railroad traffic on the Second avenue line includes about 50 passenger-train and switching movements daily, while on the three-track Colorado avenue line, about 50 freight-train and

Fig. 1. — View of westward drive on Spokane street looking west—Signal on eastward drive in left background.

switching movements are made daily. The East Marginal Way line handles from 8 to 10 switching movements daily.

Former protection.

Under the previous arrangement two watchmen were on duty each of three tricks at the Second avenue crossing and the same number of men were on duty at the Colorado street crossing. Trainmen were required to flag the crossing at East Marginal Way. On account of the heavy vehicular highway traffic, the protection afforded by flagmen was not entirely satisfactory because of the dif-

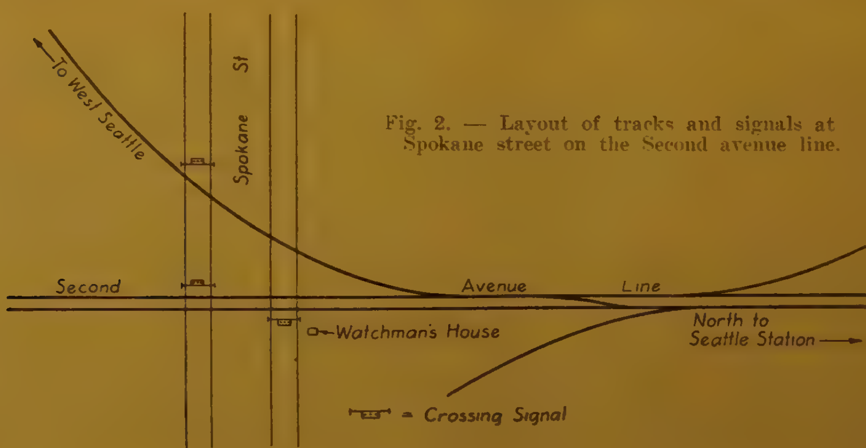


Fig. 2. — Layout of tracks and signals at Spokane street on the Second avenue line.

ficulty in stopping traffic. Conditions were so bad that it was dangerous for the flagmen to get out on the street to attempt to stop trucks and automobiles.

After several conferences between the railroad representatives and the city traffic officials, an order was issued requiring the railroad to install light signals mounted over the highway at 14 feet clearance. It was required that the signals be of the same general appearance as the traffic signals used at street intersections in the city, but that they should indicate green in the center unit when the crossings are clear for highway traffic, and that the two end red lamps should flash alternately when a train is approaching or occupying the crossing. A crossbuck sign reading « Railroad Crossing » is mounted over the signal to designate it as a railroad crossing signal and a bell is provided at each signal.

On account of the slow train speeds and numerous switching movements on the tracks at these crossings, it was not practical to use automatic track-circuit controls for the crossing signals. Therefore manual control arrangements were provided, the signals at Second avenue crossing being controlled by a watchman in a shanty at the crossing, while the signals at Colorado street are manually controlled by the leverman in the tower at an interlocking at that point. The signal lamps are rated at 60-watts, 125 volts and are equipped with a special filament designed to withstand rough service. A single-pole double-throw enclosed knife switch, operated by a handle on the front of the case, is used for the control of each signal. When the lever is in the left or normal position, 110-volt A-C. is fed to the green lamp, the red lamps being extinguished. When the lever is thrown to the right, the green lamp is extinguished and 110-volt A-C. is fed to a rectifier to operate a D-C. flasher-relay, through the contacts of which the same 110-volt circuit is fed to flash the two red lamps. The 10-volt D-C. bell is fed by a separate wire controlled by the relay.

A floodlamp reflector with a 25-watt, 110-volt lamp is mounted over each signal to illuminate the crossbuck sign. The feed for these floodlamps is on a separate circuit controlled by a snap switch, the floodlamps being illuminated continuously during the hours of darkness. Annunciators are provided to warn the watchman and towerman of the approach of trains, buttons being provided to cut out the annunciators.

In order to meet the requirement that the signals be mounted over the center of the driveway, the railroad was confronted with the problem of designing the supporting structure. At each side of the driveway, the upright mast consists of a signal mast made up of a section of 6-inch pipe 7 ft. 6 in. long, in which is set a section of 5-inch pipe 9 ft. 10 in. long. The base casting is set on a concrete foundation 2 ft. 6 in. × 3 ft. 6 in. × 6 feet. On the top of the pipe there is a standard 5-in. × 5-in. × 5-in. tee sprinkler fitting faced and drilled. The cross bar of 5-inch pipe is fitted at each end with a 5-in. × 10-in. companion flange, faced and drilled so as to be bolted to the flange on the tee. A 5-inch nipple is screwed into the top of the tee and a standard pinnacle is set on. The crossbar clears the surface of the pavement by 16 ft. 3 in. The signal is supported by pipe fittings and attached to the crossbar by clamps, the bottom of the signal clearing the pavement by 14 feet.

The wiring between the control point and each signal is in underground Parkway cable, being run in 1 1/4-inch conduit up one of the masts to an outlet, and then run in the open, supported by clamps below the crossbar to the signal.

Signals on side brackets at Landers street.

Landers street, running east and west, two blocks north of Spokane street,

crosses the Second avenue double-track line and two switch tracks. This street is used for both directions of traffic and as traffic ordinarily travels at the right, the signals are mounted on bracket arms

Fig. 3. — Side bracket mounting at Landers street.

so as to bring the center lamp 8 feet from the edge of the pavement, directly over the path of a vehicle. Likewise, on account of the street being used in either direction, one signal was required on each side of the tracks.

Each supporting structure is constructed with a mast similar to that previously described, except that the 5-inch section is 14 feet long so as to extend 4 feet higher. A 5-in. × 5-in. × 4-in. tee is reamed to fit over the 5-inch pipe and is slid down to position and held in place by a 5/8-inch through-bolt. The arm is made of a 10-foot section of 4-inch pipe screwed into the tee. A 1/2-inch round iron rod, with a turnbuckle, extends from the top of the mast to the end of the arm, as a guy.

Automatic-manual control.

For trains operating on the two center tracks, over which the passenger trains are operated, the signals at Landers street are controlled automatically by track circuits using interlocking relays. For switching movements on the two outside tracks, the operation of the signals is controlled manually by a single-pole double-throw knife switch in the switch tender's shanty near the crossing.

The operation of the signal and crossing bell is controlled directly by a 670-ohm neutral relay marked IF. This relay is controlled through the knife switch and through the two interlocking relays. Under any condition, relay IF will be released when a train approaches on either of the passenger tracks. When a train movement is to be made out of the enginehouse or coach yard, the switch tender operates the knife switch to the reverse position, which drops relay IF and starts the operation of the signals. After the rear of the train clears the crossing, he returns the knife switch to the « up » position, which stops the operation of the signal.

When a southbound switching train is approaching the crossing on either of the two outside tracks, a trainman opens the knife switch at signal 1.3 which causes the bell relay to be de-energized and starts operation of the signals. The switch tender then watches the approaching train, and, if it is delayed in making switching moves, he can cut out the operation of the signal by operating his knife switch to the full « down » position. Regardless of the position of the knife switch, the approach of a train on either of the two main tracks will start the operation of the signal automatically.

Flashing-light signal at Tacoma.

In Tacoma, D-street crosses the Head of Bay line of the Northern Pacific, involving a group of tracks, of which two are main lines, one is a lead to a yard, three are leads to the roundhouse and

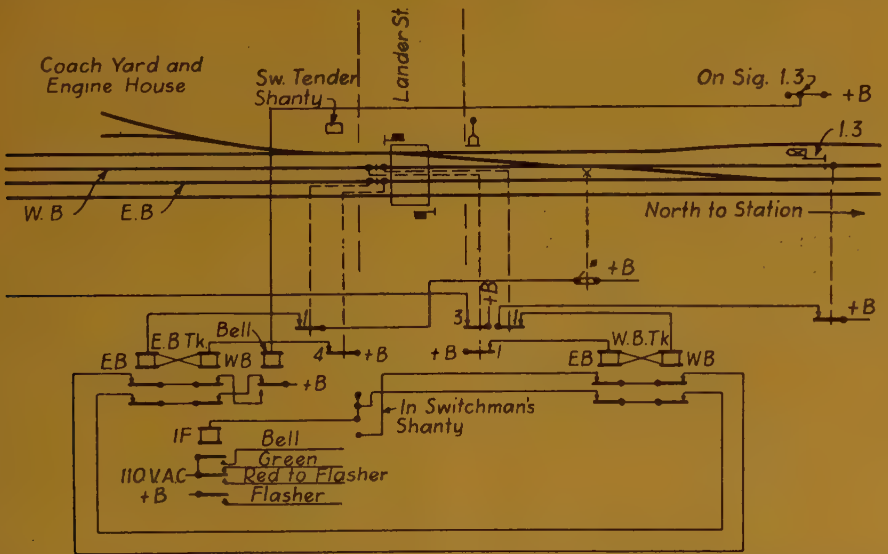


Fig. 4. — Diagram of combined automatic and manual control for signals at Landers street.

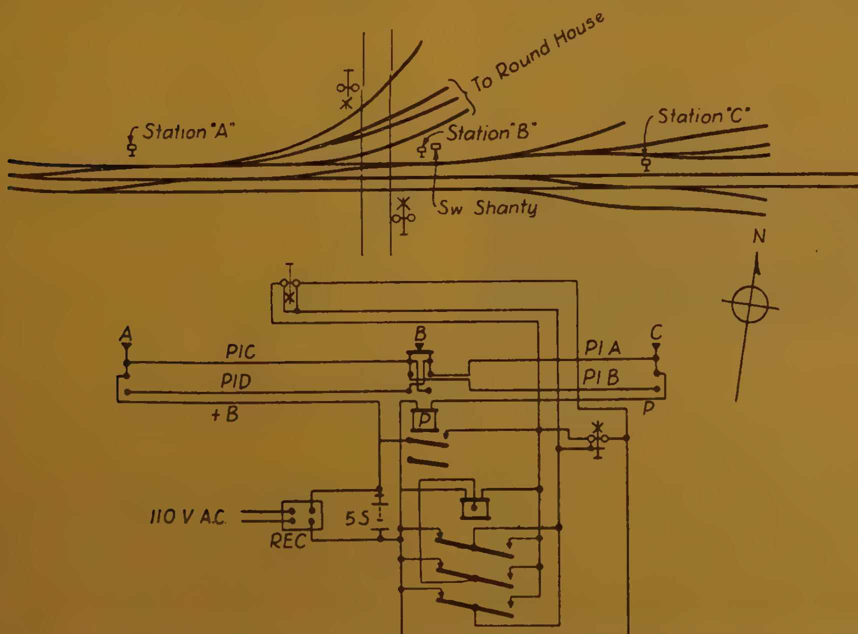


Fig. 5. — Manual control circuits of flashing-light crossing signals at D-street in Tacoma.

one is a track leading to a freight house and industries.

The main lines are used principally by Northern Pacific and O. W. R. R. & N. passenger trains, and also two Great Northern passenger trains use this track daily. On account of the numerous switching moves and engine moves in and out of the roundhouse, it is not practicable to control the crossing signals by track circuits. However, the street traffic is fairly heavy, especially during the day when numerous trucks are operating in this dock and mill district. After considerable study of the circumstances, the signal department developed an idea of using manual control for the proposed crossing signals, and the system as now installed has proved quite satisfactory in protecting street traffic and in expediting train movements.

Fig. 6. — View of flashing-light crossing signals at D-street in Tacoma.

The signals are the standard flashing-light type with 8 3/8-inch lenses and 10-volt 18-watt lamps. The control arrangement includes three control stations or boxes, each equipped with a two-position knife switch, the circuits being so designed that the operation of the signals can be started or stopped from any one of the three stations. One control station is located at the crossing; one north of the tracks at a point 300 feet west of the crossing; and the third between the main line and yard track at a point 240 feet east of the crossing. At each of these stations the knife switch is located in a cast-iron box with a tight-fitting door.

The control circuit includes a 670-ohm relay, marked *P* in the diagram, which when picked up starts operation of the flasher relay. Relay *P* is so connected that operation of any of the three knife switches will cause its energization, and likewise, subsequent operation of any of the knife switches will release it. For example, if a locomotive is to come out of the roundhouse, the switch tender lines the track switches and then, as the locomotive approaches the crossing, he throws the knife switch at station *A* to start the operation of the signals. After the crossing is cleared, he returns the knife switch to its original position to stop the signal or, if he happens to return to the crossing in the meantine, he can operate the knife switch at station *B* to stop the signal. If a train is switching east of the crossing and is ready to move over the crossing, one of the trainmen throws the knife switch at station *C* to start the operation of the signals and after the train has cleared the crossing, he can stop the signal operation in the same way.

Flashing-light signals at Airport crossing.

At a point nine miles south of Tacoma, the Prairie line of the Northern Pacific crosses a highway leading to the airport, and a branch line extending by way of American Lake crosses the same highway as well as the main Tacoma-Portland highway known as

Figs. 7 and 8. — Track and signal layout together with special circuits for installation at Airport crossing.

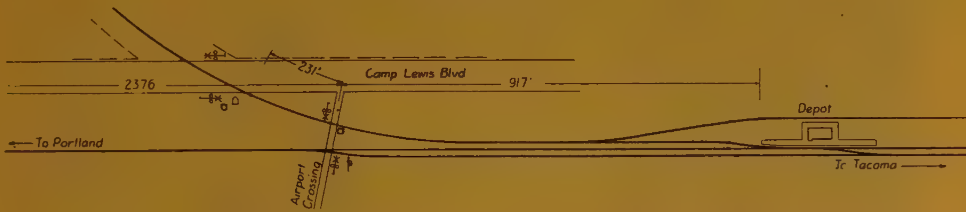


Fig. 7.

Camp Lewis boulevard. The traffic on the main line includes two passenger trains and four freight trains daily, while a mixed train is operated each way daily over the American Lake branch.

The crossing signals installed at these crossings are of the standard flashing-light type, using 8 3/8-inch lenses and 10-volt 18-watt lamps. The signals are controlled automatically by track circuits with some special interconnected circuits. For train movements in either direction on the main line, the control is effected by track circuits operating an interlocking relay. When a southbound American Lake line train stops at the station, it is occupying the track circuit *A1* which, of course, causes the crossing signals at the Airport crossing to be in operation. When the train completes its station work and pulls over the switch on to the branch line, the signals at the Camp Lewis boulevard crossing are also started in operation. Interlocking relays function to cut out signals when the rear of the train passes over the crossing in each instance.

When a northbound train on the American Lake line passes over the crossings, the signals are cut out. When the train stops at the junction and the switch is thrown, the signals at Airport crossing do not again start

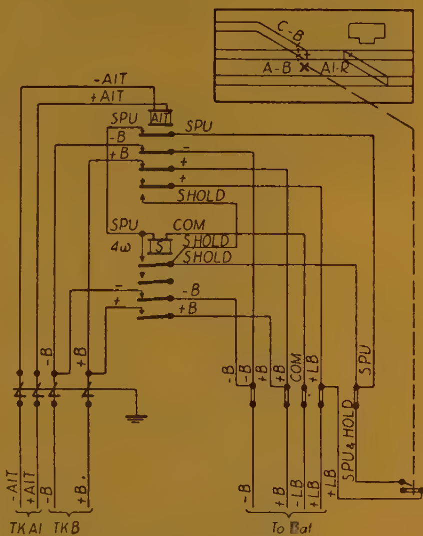


Fig. 8.

operating because the circuits are so arranged that the signals will not operate when the train pulls into the track circuit on the main line. This is accomplished as shown in the circuit diagram. Ordinarily the feed for track circuit *A* is taken through front contacts of the relay for track circuit *A1*. When the switch is thrown, a circuit is completed which picks up stick relay *S*, through the front contacts of which battery is fed to track circuit *A*, independent of relay *A1T*.

Fig. 9. — Flashing-light signals on Camp Lewis boulevard crossing of the American Lake line.

After the train is out on the main track on track circuit *A1* and the switch is placed normal, the stick relay stays up through a back contact of relay *A1T*. The stick relay is released when the train clears track circuit *A1* and picks up relay *A1*. Therefore, the signals are not operated for such a receding train movement. It should be noted that this circuit is accomplished without the use of line wires.

MISCELLANEOUS INFORMATION.

[621. 132.8 (.42) & 621. 135 2 (.42]

1. — The London Midland and Scottish Railway turbine locomotive.

Details of the roller bearing axleboxes.

(*The Railway Gazette.*)

As stated in a previous article (1), the turbine express locomotive completed at the Crewe works of the L. M. S. R. in June last is fitted with roller bearing axle-boxes throughout, and this is the first time in the history of British railways that a locomotive has been fully equipped with anti-friction bearings on all axles. Twelve single-row and eight two-row bearings of Timken manufacture are used to carry the complete locomotive and tender, which has a weight of nearly 164 tons. Four different types of axlebox have been incorporated, each designed to meet the individual conditions imposed by its position.

Both axles of the leading bogie are carried in the Timken type of cannon box mounting having at each end a single-row taper roller bearing of 13 5/8 in. outside diameter, to carry a wheel load of 9 tons 12 cwt. The single bearing has been adopted as providing the maximum thrust load capacity, so desirable in this position. The radial load is divided between the two bearings. The bearings run in an oil bath, and advantage has been taken of the centrifugal pumping action of the tapered construction to provide an automatic oil circulatory system through the bearings. Cored passages are arranged in the lower half of the boxes for this purpose. The enclosures at each end of the axleboxes incor-

Fig. 1. — Complete axlebox and bearing assembled on driving axle of L. M. S. R. 4-6-2 turbine locomotive.

(1) *The Railway Gazette*, June 28, 1935, pp. 1251-1260. *Bulletin of the Railway Congress*, October 1935, pp. 1239-1252.

porate an oil flinger and oil grooves, which prevent the escape of oil and the penetration of dirt and water. Oil wastage is small and replenishment infrequent.

The axlebox is of cast steel, split on the horizontal centre line and secured with fitted bolts. The design facilitates inspection of the bearings, although this is necessary only after long intervals.

Driving axle bearing.

This application called for special care and consideration owing to the flexible drive in the centre of the axle, combined with a heavy load of 22 tons 13 cwt. at rail. Two boxes are employed on an axle, each equipped with a self-contained double-row Timken bearing of 19 in. outside diameter. The bearings are mounted indirectly, that is with the small ends of the tapered rollers pointing towards one another, which ensures the maximum stability. The boxes are of cast steel, and are split horizontally on the centre line. The halves are secured by six long bolts of high tensile steel, which carry the journal load. The bearings run in an oil bath, the box having ample oil capacity; automatic oil circulation, as previously described, is provided.

The Timken patented trunnion horn guide, of special alloy steel, mounted on circular trunnions solid with the boxes, has been adopted. The flexibility allowed by this construction makes for smoother working and reduced wear. The horn guides are lubricated on all wearing surfaces from a felt plug recessed into the top of the horn guide, which is fed with oil by a wick trimming, from oil pockets cast on the top of the axlebox.

The horn guide proper is a separate component rotatably mounted on a circular trunnion on the box, and any tilting motion of the axlebox relative to the guide members on the frame, due to track irregularities, etc., is readily accommodated by a slight angular movement of the horn guide. This arrangement permits much greater flexibility and at the same time no portion of the stucture is subject to undue stress or wear.

To ensure complete lubrication of all wearing surfaces, an oil reservoir fitted with a cover plate is provided on the top of the axlebox and a circular felt pad projecting through the trunnion guide to its face is let into the wall of the reservoir, and is fed with oil by means of a wick trimming. The angular movement between axlebox and horn guide, previously mentioned, tends to shear the felt pad slightly. This squeezes out the lubricant drawn from the reservoir, which then runs down between the trunnion guide and adjacent faces to lubricate thoroughly all wearing surfaces.

The boxes for the intermediate and trailing coupled axles are of the cannon box type, of a design generally similar to those of the leading bogie, but with the addition of the trunnion type horn guides as fitted to the driving axleboxes. Single-row Timken bearings of 19 in. outside diameter are used to carry the heavy axle load of 24 tons. The single axle of the trailing truck (Bissel type) is mounted in two boxes, each containing two


Fig. 2. — Timken cannon box type roller bearing assembly, for a steam railcar supplied to the Belgian National Railways Company.

single-row bearings of 13 1/4 in. outside diameter to carry an axle load of 18 tons 3 cwt. The indirect bearing arrangement is used; the axlebox is a single casting, closed by a cover at each end. Owing to the proximity to the firebox, special provision is made for the exclusion of ashes and water.

The tender is of the six-wheeled type, weighing fully loaded 54 tons 13 cwt. The Timken bearings in each of the six axleboxes are of the double-row type having an outside diameter of 12 1/8 in. with direct mounting, i.e., the small ends of the taper rollers point away from each other. The axleboxes are single steel castings, provided with outer covers and the automatic oil-circulatory system; the design is generally similar to that usually adopted for passenger coaches.

These bearings minimise the pounding of reciprocating parts by supporting the axle round the whole of the circumference with only a fine radial clearance.

Figure 1 shows a driving axlebox on the L. M. S. R. turbine locomotive, and figure 2 a similar assembly in complete form for a steam railcar built by the Birmingham Railway Carriage & Wagon Company for service on the Belgian National Railways.

[621. 132.3 (.73) & 621. 132.8 (.73)]

2. — Atlantic type streamlined locomotives, Chicago, Milwaukee, St. Paul & Pacific Railroad.

(*The Railway Gazette.*)

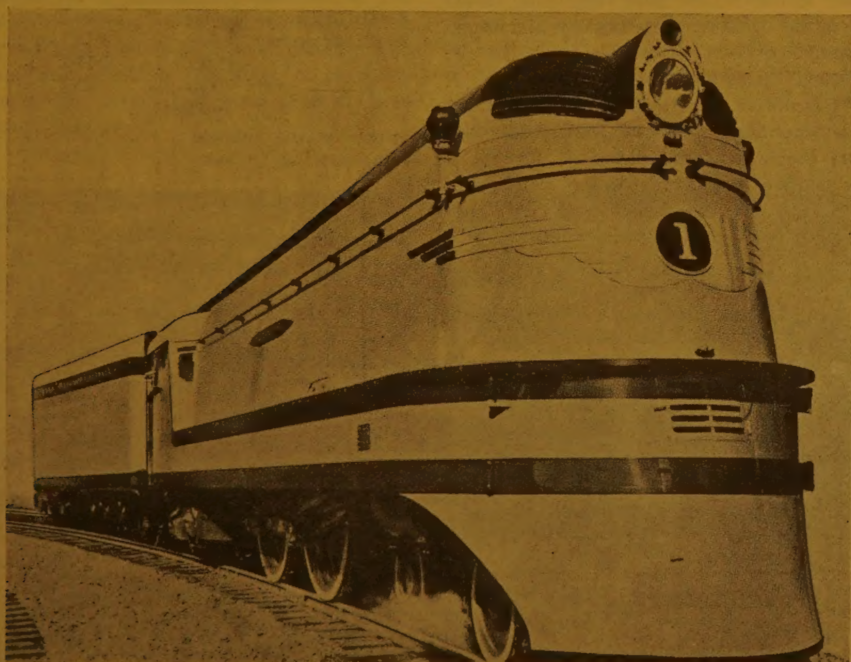


Fig. 1.

By the courtesy of the American Locomotive Company we are enabled to reproduce herewith photographs and give particulars of the new high-speed, high-power, streamlined oil-burning steam locomotives recently completed for the Chicago, Milwaukee, St. Paul & Pacific

Railroad for hauling the new Hiawatha *de luxe* streamlined train between Chicago, St. Paul, and Milwaukee. The locomotive will be required to cover the 410 miles in 390 minutes, including five intermediate stops, at an average speed of 66 m.p.h.

The *de luxe* passenger coaches of which the train is composed weigh approximately 50 tons each, as compared with the 85-ton Pullmans now commonly used on the American railways. Even so, the new cars are considerably heavier than many of the extremely light passenger vehicles recently introduced on American high-speed runs. They are streamlined, and the rear vehicle of each set is provided with a wedge-shaped or « beaver tail » end designed to improve the air flow past the train at high speeds. Forty passengers are accommodated in each of the day coaches, which is one-third less than usual owing to the wide centre gangway and smoking lounges at each end. The train is air-conditioned throughout.

The locomotive is of the 4-4-2 type and has a tender mounted upon two bogies, one with six and the other four wheels.

The engine in working order weighs 125 (long) tons, and the tender 110 1/2 (long) tons; each pair of coupled wheels carries 31 1/4 tons, giving 62 1/2 tons total adhesion weight. The maximum tractive power is 30 700 lb. and the factor of adhesion 4.56. The tender capacity is 13 000 gallons of water and 4 000 gallons of fuel oil. S. K. F. roller bearings are fitted on all the engine and tender axles. A series of wind tunnel tests of locomotives and trains of various lengths, contours, and degrees of streamlining was carried out by makers in connection with the design. The coaches are equipped with Timken roller bearings.

The following are the main dimensions of the locomotive :

Cylinders, diameter . . .	19 in.
Piston stroke	28 in.
Wheels, coupled, diameter .	7 ft.
Wheelbase, engine	37 ft. 7 in.
» coupled . . .	8 ft. 6 in.
» engine and tender	78 ft. 10 1/2 in.
Boiler, steam pressure . .	300 lb. per sq. in.
Heating surface, tubes . .	1 781 sq. ft.
» » flues . .	1 170 »
» » firebox .	254 »
» » syphon .	40 »
Total heating surface . .	3 245 »
Superheating surface . .	1 029 »
Combined total	4 274 sq. ft.
Grate area	69 sq. ft.

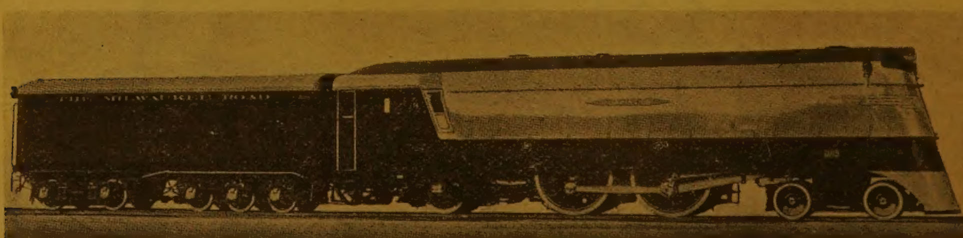


Fig. 2. — Broadside view of new 4-4-2 streamlined locomotive for the Hiawatha high-speed express.

[621. 133.2 (.72)]

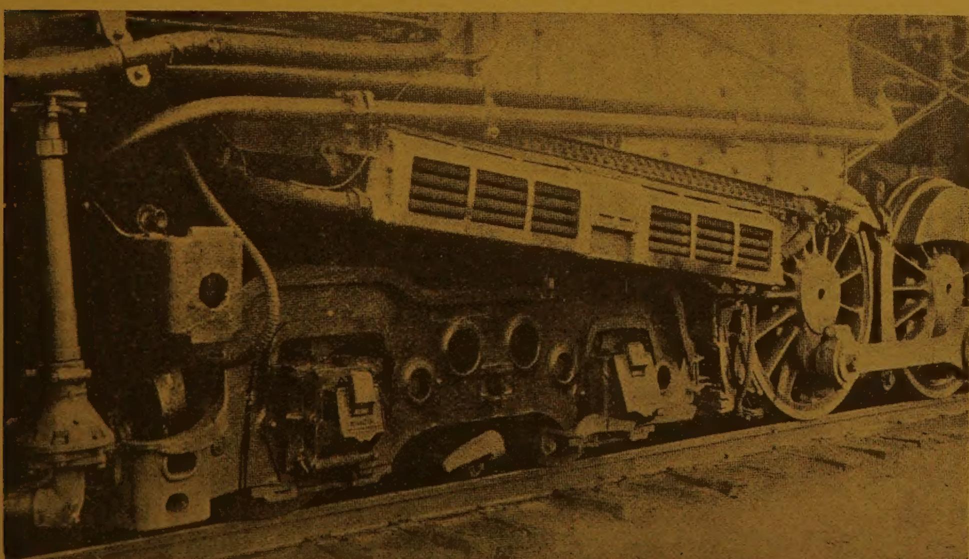
3. — Air preheater for locomotive fireboxes.

(Railway Age.)

One of the recent developments of the Lima Locomotive Works, Inc., New York, is an air preheater for locomotive fireboxes designed to raise the temperature of the air used for combustion in order to effect uniform combustion conditions, fuel economy, an increase in evaporative efficiency, and a reduction in firebox maintenance. In the conventional locomotive side-sheet maintenance is aggravated due to cold air coming in contact with the side sheets, and their consequent expansion and contraction causes warped and cracked side sheets and leaky staybolts and rivets. A preheater of this type was applied to a modern 2-10-4 type locomotive and has now been in service for approximately 18 months. The locomotive so equipped is said to have shown a marked reduction in side-sheet maintenance, warping and cracking. Leakage of staybolts and mud-ring rivets has been reduced to a minimum.

Tests were made in January, 1934 of two locomotives of identically the same design, except that one was equipped with the preheater and the other was not, and for the preheater locomotive an average fuel saving per unit of work of between 7 and 8 % was indicated and the evaporation per pound of coal was correspondingly increased. At the time these tests were made the average outside temperature was 32 degrees. Readings taken simultaneously at four different locations within the ashpan showed that the temperature of the air entering the ashpan averaged 205 degrees.

Some idea of the manner in which the preheater is applied may be gained by reference to the accompanying illustration. The heater is applied in two sections, one on each side of the firebox directly under the mud ring. The heater sections are comprised of casings, each containing a number of finned tubes.



View of a 2-10-4 locomotive equipped with the firebox preheater.

The tubes are located relatively close together and in staggered fashion so as to provide maximum efficiency in heat transfer. The tubes extend lengthwise through the heater section and terminate in tube sheets. The fins lie in lines paralleling the general path of the air in flowing through openings into the heater, the air thence being discharged just below the grate. With this arrangement all of the air for combustion purposes must pass through the preheater, thus raising the temperature before it reaches the fire bed.

There is an opening between the two heater sections and also at each corner below the mud ring, which are normally closed by doors. These openings provide access to the ashpan for cleaning.

Steam is circulated through the heater sections, each of which operates separately. When the locomotive is in operation the steam is taken from the exhaust passages of the cylinders and carried direct to the air preheater units. When the steam is shut off from the main cylinders and the locomotive is drifting or standing, the steam is taken from the main turret and passes through a reducing valve which reduces the pressure to 15 lb. per sq. in. before it passes through the lines to the preheater units. The change from the use of exhaust to live steam and vice versa is automatically accomplished by valves of special design. When the steam is being admitted to the main cylinder the valve in the line closes the live-steam connection from the turret and the automatic valve in the line from the cylinders to the preheater unit is opened, thus permitting the passage of exhaust steam. When the steam is shut off from the main cylinders this operation is reversed.

The steam is led to the back end of each heater section. All of the heater tubes are constantly filled with steam; the inflow of air around the tube condenses the steam, causing it to give up its heat. The condensate is led to a trap and discharged to the ground, or may be led, by suitable means to the water space in the tender, if this is desired.

Shut-off valves are applied so that the heater can be made inoperative without interfering with the operation of the locomotive. A blower fitting is provided in the line from the turret so that steam can be applied to the heater when the locomotive is being fired up. The entire arrangement is automatic in operation and requires no attention on the part of the engineman. Each of the heater sections is so designed as to be interchangeable. The preheater arrangement is covered by pending patent applications.